Universidade de Aveiro Departamento de Economia, Gestão e Engenharia Industrial
2007

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China's Innovation System and Industrial Competitiveness in the Global Context

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Tese apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Doutor em Gestão Industrial, realizada sob a orientação científica do Professor Doutor Joaquim José Borges Gouveia, Professor Catedrático e a co-orientação científica da Professora Doutora Celeste Maria Dias Amorim Varum, Professora Auxiliar do Departamento de Economia, Gestão e Engenharia Industrial da Universidade de Aveiro.

Apoio financeiro da FCT e do FSE no âmbito do III Quadro Comunitário de Apoio.

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Agradecimentos

I thank my advisor Prof. Borges Gouveia for his tremendous support and patient guidance and co-advisor Prof. Celeste Amorim Varum for her inspiring discussion and advices over the past four and half years. I am indebted to my visiting research advisor Prof. Susan Cozzens in School of Public Policy, Georgia Institute of Technology in the United States of America for her relentless encouragement and great help. I am grateful to my close collaborators Prof. Yanyun Zhao, Prof. Naubahar Sharif, Prof. Mingqian Zhang, Ms. Zhe Qu, Dr. Xinxin Kong, Dr. Jiang Jiang, Dr. Jun Tu for their selfless and valuable aid in writing this thesis. I thank Prof. Augusto Medina for his help and support for many years. Without Prof. Augusto Media's effort, I would not have chance to pursue my PhD study in University of Aveiro. I also thank Ms. Elena Harari for helping me translate the summary.

Palavras-chave

Sistema Nacional de Inovação, Produtividade Cientifica, Empresa de Manufactura, China

Resumo

O presente estudo compõe-se de quatro artigos científicos coerentemente organizados sob o tema geral do sistema de inovação Chinês e a competitividade industrial da China no contexto mundial.

Baseado nos conceitos da Teoria dos Sistemas Nacionais de Inovação, a presente pesquisa identifica os intervenientes na definição e implementação das politicas de inovação na China, comparando-os com um conjunto seleccionado de países membros da Organização para a Cooperação e Desenvolvimento Económico. O estudo utiliza as práticas destes países da OCDE como guia para analisar o sistema de inovação Chinês em cinco categorias: reforma das instituições públicas de Ciência & Tecnologia (C&T), politicas de financiamento, estrutura de suporte para a inovação no sector privado, politicas de recursos humanos, bem como acções legislativas. Através de uma análise detalhada, a pesquisa identifica os pontos fracos das políticas de inovação no país, nomeadamente: politica de educação e de recursos humanos, e direitos da propriedade intelectual.

Tendo por fundo o desenvolvimento do sistema de inovação Chinês, analisa-se com mais detalhe a transformação do sector de C&T herdado da economia centralizada. De modo a avaliar o impacto das reformas na eficiência do sector, quantifica-se produtividade científica dos institutos de C&T chineses. Os investimentos (inputs) e resultados (outputs) em termos de investigação e desenvolvimento (I&D) são analisados a nível nacional e regional através do modelo econométrico Polynomial Distributed Lag Model. Os resultados revelam uma taxa de crescimento da produtividade científica negativa nos institutos de pesquisa chineses desde a década de 1990.

A indústria e a política de inovação fortalecem a competitividade empresarial da China no mercado global. Utilizando dados de mais de 95.000 empresas de manufactura, o estudo analisa os factores que influenciam o recente crescimento das exportações de produtos manufacturados da China. A inovação de produto, a colaboração com investidores estrangeiros, e a forte concorrência no mercado nacional aumentam a probabilidade de entrada de empresas chinesas no mercado internacional. O custo unitário de mão-de-obra não aparece como factor decisivo para o sucesso das exportações das empresas chinesas. Investimentos em I&D também não contribuem para a competitividade das exportações chinesas, mesmo em sectores de alta tecnologia. Empresas estrangeiras dominam as exportações de produtos de alta tecnologia, mas têm investido menos em I&D do que as firmas nacionais.

Visando analisar a inovação e a dinâmica industrial na China de uma perspectiva regional, o estudo caracteriza a interdependência económica

mútua entre a província de Guangdong e a Região Administrativa Especial de Hong Kong situada no sul da China. Os resultados mostram que entre 1997 e 2003, na província de Guangdong, a produtividade das empresas de manufactura de capital Chinês foi mais alta do que a das empresas estrangeiras - a maioria tem capital de Hong Kong. Há pouca evidência de que na província de Guangdong, a actividade económica das empresas estrangeiras de Hong Kong tenha contribuído para o crescimento da produtividade das empresas domésticas.

Sob o tema geral do sistema de inovação Chinês e da análise dos tópicos específicos ressaltam várias implicações para o futuro da política de inovação na China. Primeiro, argumenta-se que fortalecimentos do investimento em educação e dos regimes legais e administrativos de direitos de propriedade intelectual são prioritários. Segundo, reformas futuras do sector de C&T deve enfatizar melhoria do sistema de financiamento, fortalecimento da gestão interna das instituições de C&T e controlar as actividades ilegais. Terceiro, em termos de crescimento de produtividade e fortalecimento da competitividade industrial, o desenvolvimento de capacidade local é vital para uma economia em desenvolvimento como a da China.

Keywords National Innovation System, Scientific Productivity, Manufacturing Firm, China

Abstract

This study is mainly composed of four research papers with different emphases, but coherently organized in the overarching theme of China's innovation system and industrial competitiveness in the global context.

This research identifies the stakeholders involved in the design and implementation of China's innovation policy and compares them with different government systems in the selected Organization for Economic Co-operation and Development (OECD) countries. It examines China's innovation policy in five categories: reform in the public S&T institutions, financial policy, business innovation support structure, human resource policy and legislative actions. Education and human resource policy and protection of intellectual property rights are identified as weak components of the Chinese innovation policy framework.

The study further examines the transformation of China's Science & Technology (S&T) sector inherited from the planned economy. To disclose the impact of the drawn-out reform on the efficiency of the whole sector, the research measures the scientific productivity of China's S&T institutes. The R&D input and output data analysis is implemented at country aggregate and provincial level. Polynomial Distributed Lag model is used to uncover the structure of the lag between R&D input and output. The findings reveal that the growth rate of scientific productivity of China's S&T institutes has been negative since the 1990s.

The successful industry and innovation policy significantly strengthens the competitiveness of Chinese enterprises in global market. Using the data of more than 95,000 Chinese manufacturing firms, the study explores the reasons for China's recent manufacturing export growth. Product innovation, collaboration with foreign investors and fierce competition increase the probability that Chinese firms enter international market. Unit labor cost and R&D investment are not decisive factors determining the export success of the firms, even in high-technology sectors. Foreign manufacturing firms dominated China's high-technology product export, but they devoted less resource to R&D investment than domestic counterparts.

To study China's innovation and industrial dynamics from the regional perspective, this study characterizes the context of mutual economic interdependence between Guangdong province and Hong Kong Special Administrative Region in Southern China. It shows that, in the years 1997-2003, domestic manufacturing firms in Guangdong gained on their foreign-funded counterparts—dominated by Hong Kong-based companies— in productivity. Little evidence is found that the economic activity of Hong Kong-funded enterprises contributed to productivity growth in domestic manufacturing firms in Guangdong.

Covering the general and specific issues of China's innovation system, the analyses of the thesis reveal several implications to the future innovation policy making in China. We argue firstly that strengthening investment in education and the legal and administrative regimes for intellectual property rights must be set as priorities. Secondly, China's future S&T reform policy needs to emphasize continuous improvement of the funding system, strengthen the internal management of the S&T institutions and fight misconduct activities. Thirdly, establishing indigenous innovation capability is vital for a developing country such as China in terms of boosting productivity growth and enhancing industrial competitiveness.

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List of Symbols and Abbreviations

CEEC	Central and East European Countries
CHTF	China High-Technology Fair
EU	European Union
GDP	Gross Domestic Product
HKMT	Hong Kong, Macau and Taiwan
ICT	Information and Communications Technology
IPO	Initial Public Offering
IPR	Intellectual Property Right
MOST	Ministry of Science and Technology
OECD	Organization for Economic Cooperation and Development
PCC	Productivity Promotion Center
SCI	Science Citation Index
SOE	State-owned Enterprises
S&T	Science and Technology
TFP	Total Factor Productivity
TVE	Township and Village Enterprises
WEI	World Education Indicators
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

Chapter 1: Introduction

China started its reform of the planned economic system in the late 1970s. As described in Chapter 2 of this thesis, the gradual transformation of the Chinese economy began from the rural area first and then expanded to the industry sector. The reform overhauled the micro- and macro-level economic policies and the foreign trade and investment institution. Market oriented economic system has been established to govern the Chinese economy, though lasting effort is still needed to transform the remaining planned institution and improve the efficiency of the current system.

Over the past two decades, China intended to promote economic and social transformation through a coordinated Science & Technology (S&T) and innovation policy. Therefore, the Chinese innovation policy has experienced complicated and diverse changes. The transition of the Chinese innovation policy till the 1990s was described by the previous literature by International Development Research Center (1997), Gu (1999) and Lu (2000) etc. However, the swiftness in the evolution of China's institutions and organizations has made the existing literature, to some degree, obsolete. To provide the updated analysis of the strengths and weaknesses of China's current innovation system, we focus on the following questions in Chapter 3 of this study: Which government bodies have become responsible for innovation policy at the national level? Which organizations can be considered important participants in the process of policy making?

The Organization for Economic Co-operation and Development (OECD) (1996) indicates that an efficient innovation policy strategy must combine a number of macro-level policy actions. Its success depends on the validity of the policy framework and the mutual support among the different policy actions. The lack of coherent policy practices in certain aspects of national innovation system will limit the effect of other well-functioned policies, and thus harm the whole system. Few of the existing studies have adopted the OECD's view to organize the analysis on the Chinese innovation policy by stressing the balance and the coordination of the policies in different areas. To what extent has China developed a coherent innovation policy? In which area of the innovation policy does China do well, and where does it lag behind compared with international practices? To fill this gap of the literature and answer these questions, we examine various components of China's innovation policy framework also in Chapter 3, with the comparison to the OECD countries' practices. We identify several weak parts of the Chinese innovation system and intensively analyze two of them: education and human resource policy and protection of intellectual property rights.

The Chinese government made tremendous effort to reform the S&T system in order to establish an effective and efficient innovation system. The S&T system reform constitutes a critical part of the transformation of the whole national innovation system. The reform was launched in 1985 when "The Resolution of the Central Committee of the Communist Party of China on the Structural Reform of the Science and Technology System" was issued. Through this reform, Chinese leaders were eager to expand the successful changes in the agriculture sector that took place in the late 1970s to the industrial and S&T sectors. One of the direct impacts of this reform is that many new R&D units had been established and developed inside universities and enterprises. The S&T institutes which had formerly undertaken almost all the R&D activities in the planned era have been losing their dominance in the country's innovation system since 1985.

China's two-decade reform of its S&T system is not unique in the world. A similar transformation also took place in the post-socialist Central and Eastern European Countries (CEECs). The low efficiency of the planned S&T system in the CEECs was widely addressed by Hanson and Pavitt (1987), Meske (1998), OECD (1969) and Radosevic (1999), etc. Due to the similarities lying in the Chinese and the CEECs' planned S&T systems, we believe that before the reform, the scientific productivity of China's S&T institutes also remained at a low-level. Since a low scientific productivity prevailed in the planned system in China, it is inquisitive to ask whether the systematic reform has enhanced the efficiency of China's S&T sector. Most of the recently published literature such as those by Zhou and Leydesdorff (2005), OECD (2002) and Cao (2002) either focuses on the progress of China's scientific research and technological development measured respectively by publication and patent application, or dwells on the reform policy actions. Few of them examine the causal relationship between the policy and its performance. Is the explosive increase of China's scientific publications in recent years ascribed to the scientific productivity augmentation or is only because of the larger amount of the governmental investment? To answer these questions, in Chapter 4 we measure the scientific productivity of China's S&T institutes through adopting the econometric methodology elaborated in Adams and Griliches (1996a, 1996b) and Crespi and Geuna (2004). The findings indicate that the average annual growth rate of scientific productivity of China's S&T institutes has been negative since the 1990s, though the rapidly growing investment from the governments flew into the sector.

In market economy, firms are the driving force of innovation. Fostering and promoting innovation in firms is one of the primary tasks of a national innovation system. The global competitiveness and innovation performance of firms thus indicate the effectiveness and efficiency of a country's innovation policy. Given the vital role which firms play in a country's innovation system, in this study we give particular attention to the innovation performance of the Chinese firms to shed light on the issues such as how the innovation or industry policy affects the firms' performance and what type of policy should be implemented to improve the industrial competitiveness. In Chapter 5 we focus on the Chinese manufacturing firms' export competitiveness to identify which factors contribute to the recent surge of manufacturing exports from China. We also study the dynamism of manufacturing sectors and innovation policy actions in Guangdong province and Hong Kong Special Administrative Region (SAR) in Southern China in Chapter 6.

Since the second half of the 1990s, China's merchandise export has grown two times faster than that of the world average. In 2004, China became the biggest exporter of Information and Communications Technology (ICT) goods (180 billion US Dollars), surpassing Japan and the European Union in 2003 and taking the lead over the United States in 2004 (OECD, 2005). Since the technology- or knowledge-intensive sectors were traditionally dominated by firms in developed countries, we would like to identify the factors that contributed to the international competitiveness of these manufacturing sectors in developing countries such as China. A majority of the studies in this area examine cases of exportation in industrialized countries. Only a handful of studies such as those by Aggarwal (2002) on Indian firms, Zhao and Li (1997) and Liu and Shu (2003) on Chinese industry, and Ozcelik and Taymaz (2004) on Turkish firms have focused on the export industry in developing countries. These papers in general indicate that the success of the export business in developing countries has been attributed to the low cost of labor. However, how important labor costs are compared with other factors that determine export performance? The literature also indicates that multinational firms have been responsible for a significant portion of manufacturing transfer to developing countries. However, once they acquire transferred export business, it is not clear if the developing countries can develop the technological competence necessary to move up the ladder in the global value chain through learning by doing or technology transfer.

In Chapter 5 we answer the above questions by evaluating data of more than 95,000 Chinese manufacturing firms. We find that neither unit labor cost nor R&D investment has been a contributing factor to the export success of Chinese firms, even in high-technology sectors. Although foreign enterprises dominate high-tech exports in China, domestic firms are more committed to R&D than their foreign counterparts. However, the primary reason why Chinese firms have increased exports to foreign markets is their product innovation, connection to foreign capital, and the fierce competition among them.

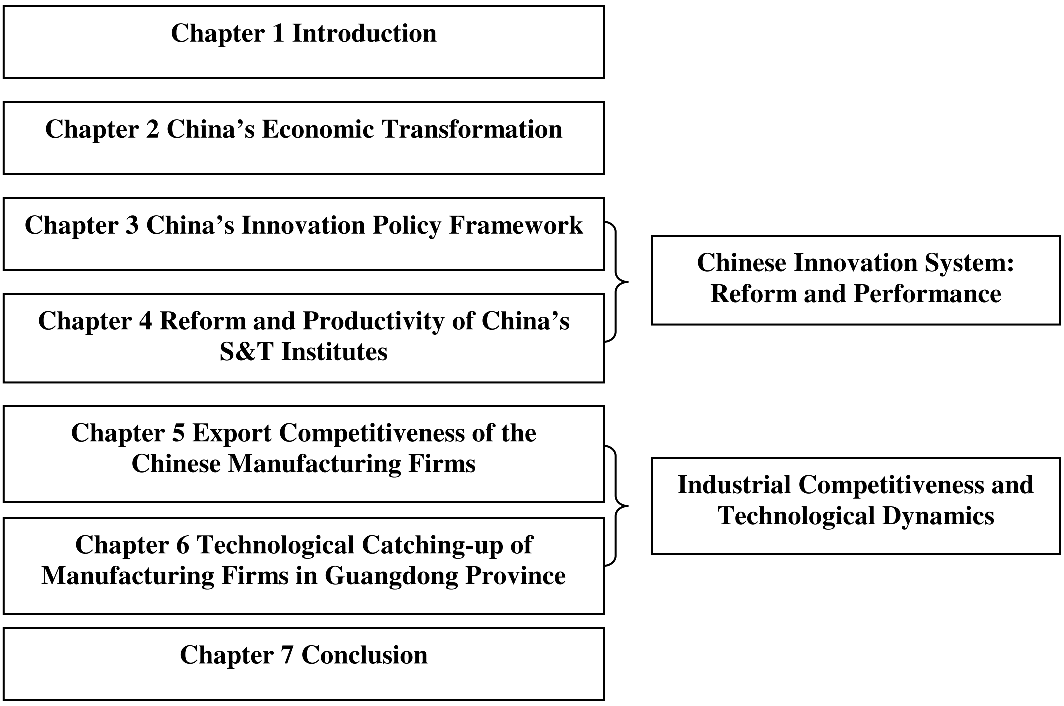
Among developing countries, China has attracted the most foreign direct investment (FDI) over the last two decades. Around one-third of FDI to China over the period 1985-2003 went to Guangdong province. Guangdong was able to attract 30 percent of China's total FDI in large part because of its geographical and cultural proximity to Hong Kong, Macau, and Taiwan (hereafter referred to as HKMT), all three of which have invested heavily in China over the past 25 years. From Hong Kong's perspective, Guangdong province is the most important investment destination in China. Since the mid 1990s, Hong Kong-based entrepreneurs have allocated almost half of their investments in China to Guangdong province. We regard that the dynamism of manufacturing sectors in Guangdong can be used as a good case to study the Chinese manufacturing firms' technological catching-up and their interaction with foreign invested companies given the fact that FDI has strong impact on China's industrial competitiveness and innovation policy. More interestingly, the productivity growth of the domestic manufacturing firms in Guangdong vis-à-vis that of the foreign invested firms which are controlled principally by the Hong Kong entrepreneurs influence the innovation policy making in these two neighboring regions.

To understand Hong Kong's economic interdependence with Guangdong, many scholars have thus far either dedicated themselves to analyzing Hong Kong's economic transition in the context of manufacturing cross-production in Guangdong (see, for example, Eng, 1997; Hollows, 1999; Kwong, et al., 2000) or focused on the two regions' economic integration from an exclusively Hong Kong perspective (Tuan and Ng, 1995, 2004). Few studies have examined the development of Guangdong's domestic manufacturing firms and their interaction with foreign counterparts, given the context that foreign businesses, principally Hong Kong-run enterprises, have flourished in Guangdong. Yeung's articles (2001, 2002) are exceptions in linking Guangdong's industrial development to the Hong Kong factor, but these studies consist almost entirely of qualitative analyses.

In Chapter 6 we center our analysis on the productivity performance of Guangdong's locally and foreign-funded manufacturing sectors over the period 1997-2003. By highlighting changes in productivity that vary with changes in manufacturing firm ownership, we reveal that domestic (Guangdong) firms have been catching up with their foreign counterparts, including Hong Kong-based firms, even though foreign firms have successfully strengthened their dominant position in Guangdong's manufacturing sectors. We then explore the potential impact of economic activity undertaken by foreign firms—both HKMT-funded and non-HKMT-funded firms—on productivity growth in Guangdong's manufacturing sectors, but find no evidence of a significant positive impact.

The rest of the thesis is organized as shown in the following Figure 1.1. Chapter 2 outlines the milestone steps of China's transformation to the market oriented economy and its gradual integration into the global economy. Chapter 3 analyzes China's innovation policy framework and compares China's practice with those of advanced OECD countries. Chapter 4 studies the reform of S&T sector in China. Through Polynomial Distributed Lag model, we measure the scientific productivity of the Chinese S&T institutes in the reform period. Chapter 5 explores the factors contributing to competitiveness of the Chinese manufacturing firms in export market. Chapter 6 takes Guangdong province and Hong Kong SAR as a case to examine the manufacturing dynamics and technological catching-up that took place in the region of Southern China. Chapter 7 concludes the thesis.

Figure 1.1: The Scheme of the Thesis

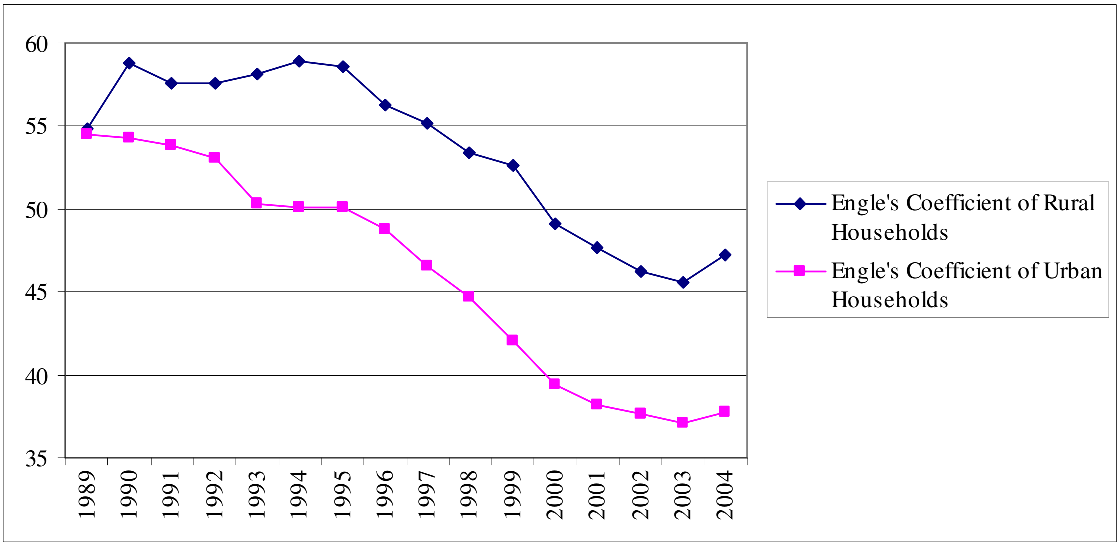


Chapter 2 China's Economic Transformation and Integration into Global Economy

China's transformation into a dynamic market economy and its integration into global economic system have been dramatic in the last quarter of the 20th century. Along with the transformation, China achieved unprecedented economic growth. Official statistics show that Gross Domestic Product (GDP) grew from 658 Billion RMB in 1978 to 6776 Billion RMB in 2004 (1990 constant price), expanding by more than 10 times. GDP per capita increased from 148 US Dollars in 1978 to 1700 US Dollars in 2005 (World Trade Organization, 2006). In 1978, on the eve of economic reform, China was the world's 32nd ranked exporting country (Lardy, 1992). In 2004 China already became the 3rd largest merchandise trader in the world after the United States and Germany (National Bureau of Statistics, 2005; World Trade Organization, 2005). China not only weathered the impact of Asian financial crisis in 1997, but also became an important source of growth for the world economy. During 2001-2003, China accounted for about 24 percent of world growth (PPP-based GDP)(Prasad and Rumbaugh, 2004).

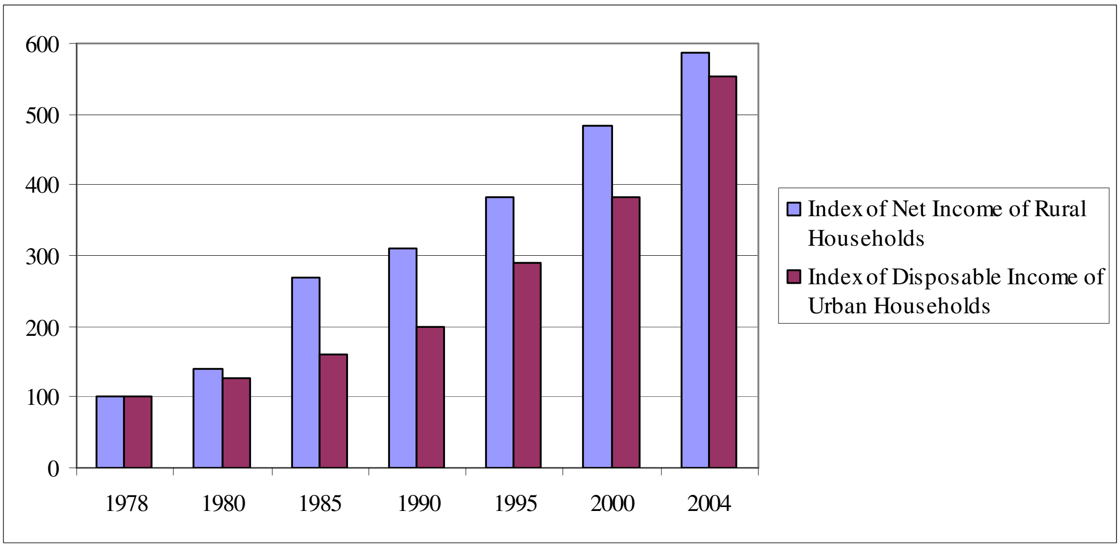
The drastic economic development significantly ameliorates the living condition of the people in the country. Measured by World Bank's 1 US Dollar per day poverty criterion, the population below the poverty line is estimated to drop from about 490 million in 1981 to 88 million in 2002 (World Bank, 2003). Rural and urban households' ratios of expenditure on food to all expenditure, known as Engle's coefficient, both declined in the past two decades. The Engle's coefficient of rural households decreased from 67.7 percent in 1978 to 47.2 percent in 2004. The coefficient of urban households fell from 57.5 percent to 37.7 percent (The change for the 1989-2004 period is seen in Figure 2.1). In line with the faster decline of Engle's coefficient of urban households, the disposal income of urban households increased more rapidly than the net income of rural households (Figure 2.2). In 2004, the disposal income of urban households and the net income of rural households were almost five times higher than their levels in 1978, respectively.

Figure 2.1: Engle's Coefficient of Rural and Urban Households (Percentage)



Source: Various issues of *China Statistical Yearbook*.

Figure 2.2: Index of Net Income of Rural Households and Disposal Incomes of Urban Households



Source: Various issues of *China Statistical Yearbook*.

The past twenty five years growth at an annually average 9.5 percent made China a 2 trillion US Dollars economy. In 2006 China surpassed the United Kingdom to become the fourth largest economy in the world. The size of Chinese economy may look less impressive given the fact that the country has a population of 1.3 billion. Nevertheless, the transformation taking place in the past quarter of the century is undoubtedly spectacular. The reform policy implemented in China gradually transformed the planned economic system to market oriented system. The open policy broke down the self-isolation and steadily integrated China into the world economy.

China's transformation from planned to market economy started shortly after the third plenary session of the 11th central committee of Communist Party of China in 1978. At the outset of the reform, there was no blueprint other than aspiration to modernize the country and raise living standard of the people in the leaders' agenda. There was no successful experience existing in other large economies, either, which could guide the transition in China. The incremental and trial and error reform process was vividly described by the late leader Deng Xiaoping as "crossing the river by groping the stones". In 1982, a concept of "building the socialism with Chinese characteristics" was put forward by the leadership as an overarching target for all kinds of reform policies. Although "the socialism with Chinese characteristics" was iterated in the addresses of the leaders, its connotation and denotation have been rather ambiguous, which provides evidence that since the outset the economic transition in China had no predetermined strategy to follow.

According to Lin et al. (2003), China's gradual transition from planned to market economy is close to Pareto improvement or Kaldor improvement. The economic agents such as enterprises and rural households were bestowed autonomy in the reform. With the incentives, they were motivated to produce more, bringing more benefit to state and themselves. This type of Pareto improvement made no one in the economic system worse off. Although some reform measures would be unavoidably against the interest of certain classes in the society, government could compensate them with the gain generated by the reform. This process is known as Kaldor improvement. The gradual transition in the nature of Pareto and Kaldor improvement diminished the resistance to the policies and contributed the political stability during the reform period.

2.1 Reform of the Economic Institution at Micro Level

The household responsibility system was the first successful reform initiative implemented across the country, particularly in China's rural area. Before its implementation, production team was the basic unit of accounting and production in rural China (Choe, 1996). The net team income was allocated to farmers who were also team members at the end of a year, based on the work points each farmer accumulated during the period. Work points were granted according to the labor days, peers' assessment of the quality of the work and the pre-assigned grade to each team member. It was extremely difficult to supervise the quality of the work in the production team system since the work points by and large were determined by the labor days, regardless of the effort that individual made in the collective agriculture work.

Under the system of household responsibility, land was allocated to households according to the number of their members. Farmers' work was neither evaluated by work points nor by labor days. Farmers were entitled to keep the production residual after paying the state tax, fulfilling the procurement quota, and contributing to public fund or welfare. They were thus motivated to increase output to have more at their disposal and accordingly there was no need to supervise farmers' work. The household responsibility system significantly boosted the agriculture production. The net value of agricultural product and grain output grew at 7.7 percent and 5 percent annually in the period of 1978-1984 (Lin, 1997). The system also greatly enhanced the living standard in rural area, so it gained popularity among farmers shortly after its implementation.

Transforming the planned industry sector in China was implemented through two parallel channels, which are reforming state-owned enterprises (SOEs) and facilitating the establishment of firms with diverse ownership such as collective, private and foreign firms, etc. As Zhang (1997) argued, the reform of state-owned enterprise at the early 1980s aimed to distribute the decision rights and residual claim from central planned authority to managers of enterprises. The policies launched in the period allowed SOEs to retain part of profit as bonus to managers and employees, decentralized fiscal authority and allocated the administrative power to local government and ministries, all of which enhanced the autonomy of SOEs. In the mid and late 1980s, the reform policy advanced to replace the profit remittance of SOEs by corporate tax. Direct fiscal appropriation was changed to indirect bank loans. The contract system was implemented in large and medium SOEs and some small ones were allowed to be leased (Qian and Wu, 2003).

However, even with these measures SOEs still lost market share in the competition with private and foreign firms. The governments had continuously subsidized SOEs through appropriating fiscal funds or indirect bank loan until the late 1990s. Policy makers realized that merely enhancing autonomy of SOEs was not enough for improving their productivity and efficiency to the extent that they could compete effectively against private and foreign companies. Therefore, in 1997 a drastic reform policy of shedding small SOEs and retaining the control of large ones was carried out. The number of SOEs in industry sector dropped precipitously from 110000 in 1997 to 53489 in 2000. Frazier (2006) estimated that about half of the Chinese SOEs, which were typically small, were privatized, shut down or converted to the firms with different ownership. Along with this dramatic restructuring of the state sector, 40.3 million people were laid off between 1995 and 2002, but non-state-owned sectors only created 16.8 million jobs at the same time (Frazier, 2006).

As the reform of state-owned industry sector went further, how to manage the remaining state-owned assets, many of which are large enterprises, became a high prioritized issue in the leaders' agenda. State-owned Assets Supervision and Administration Commission was established in 2003 to assume the responsibility of "investor" of state-owned assets. The Commission aims to preserve and increase the value of state-owned asset through enhancing management of the enterprises, establishing effective corporate governance system and strategic adjustment of the structure of state sector.

While reforming SOEs, the Chinese government removed the restriction of setting up non-stated-owned enterprises such as private and cooperative companies after the late 1970s. It also allowed foreign firms to establish joint ventures with Chinese partners. Less plagued by principal agency problem and operated under the harder budget constraints, non-state-owned enterprises achieved higher productivity than their state-owned counterparts (Jefferson et al, 1996; 2000). The diversification of ownership triggered the subsequent high-speed expansion of private and foreign sectors. The non-state-owned enterprise soon became the engine of economic growth and industrialization. The output of SOEs accounted for 78 percent of national industrial output in 1978, but the proportion was down to 43 percent in 1993, and it continuously declined in the second half of the 1990s (Table 2.1). The share of SOEs in commerce sector decreased from 55 percent in 1978 to 40 percent in 1993 (Qian and Wu, 2003).

Among the non-state enterprises, the local government-controlled collective enterprises, known as township and village enterprises (TVE), grew remarkably in the 1980s and early 1990s. Kung and Lin (2007) summarized several reasons accounting for the extraordinary development of TVEs in rural China, which include the political institution in the 1980s favored market-oriented but public owned enterprises such as TVEs; Fiscal decentralization provided incentives for local cadres to promote the development of public enterprises under their purview; once the oppressed demand for consumer products was released in the early 1980s, abundant market opportunities were created for TVEs; and regulated by relatively hard budge constraint and winning the favor of state-owned banks, TVEs received massive loans from banking system. Due to the above reasons, from 1980 to 1995, the output of TVEs grew at an average annual rate of more than 30 percent. In 1995, TVEs produced 44 percent of total industry added value and employed 28 percent of China's total rural labor force (Ministry of Agriculture, 1998). However, since the mid 1990s, as the governments progressively removed the restriction on the private sector, majority of TVEs were either privatized or turned into shareholding companies.

Table 2.1: Breakdown of China's Industry Added Value (Percentage): 1998-2004

	1998	1999	2000	2001	2002	2003	2004
State-owned or State-controlled Enterprises	57	56	54	52	48	45	42
Collective Enterprises	30	26	22	18	16	14	12
Shareholding Enterprise	N.A.	N.A.	29	37	40	42	44
Foreign Enterprises including Hong Kong, Macau and Taiwan-invested Enterprises	21	22	24	25	26	28	28
Private Enterprises	N.A.	N.A.	5	8	10	13	15

Source: Various issues of *China Statistical Yearbook*

Note: 1. Part of state-owned or state-controlled enterprises could be shareholding enterprises. Thus the sum of the percentage in the table would surpass 1.

2.2 Macro-economic Policy Reform

The reform aiming to establish market-oriented macro-economic institution includes price reform, foreign exchange rate reform, tax and fiscal reform and financial system reform. Different from the "shock therapy" policy implemented in Russia, China adopted a "dual track" mechanism to transform its "planned price". The price of planned quantities that enterprises produced was maintained in the reform period while the price of the products at the margin was freed up. The economic agents had incentive to produce more after that their obligations defined by the planned system were fulfilled (Lau et al., 1997). This incremental reform was successful in the sense that the change is Pareto-improving and the planned track was gradually phased out in the early 1990s. By 1993, 82.7 percent of agriculture products, 84.6 percent of consumer goods, 81 percent of industrial production materials and 30 percent of service charges had been traded with market price (Garbaccio, 1995).

China's reform on foreign exchange rate unfolded in 1979. Internal Settlement Rate, which came into force in 1981, was applied to trade-related foreign exchange transactions, and a more appreciated official exchange rate was used to non-trade-related transactions such as remittances and tourism (Lin and Schramm, 2003). This Internal Settlement Rate was abandoned in 1985 because it brought severe distortions to the foreign exchange market. In about the same time, the foreign exchange swap market was established, where foreign-funded enterprise and domestic institutions could swap actual foreign exchange. On January 1, 1994 the official and swap market rates were unified at the swap market rate of RMB: US Dollar = 8.7:1 that prevailed at the end of 1993. It was in 1996 when China allowed the convertibility of current account. And one decade later in July 2005 China moved one step further toward full convertibility by replacing the peg of RMB against the US Dollar with the linkage of the exchange rate of RMB to a basket of foreign currencies.

China's fiscal system reform between the late 1970s and 1994 was characterized by revenue sharing and fiscal decentralization. In the fiscal reform, the role of public finance in the economy was reduced. Provincial governments obtained considerable budget authority through a series of negotiation with the central government, and the revenue sharing arrangements with central government differ greatly among different provinces. In 1994, a new round of fiscal reform was launched, which aimed to strengthen the central government's fiscal authority over the localities and restrained the bargaining between the central and local governments. The new fiscal system distinguished the national and local taxes and collected them separately by national tax bureau and local tax bureau. The reform curbed the decline of the ratio of budgetary revenue to GDP and the ratio of central government's budgetary to total budgetary revenue (Loo and Chow, 2006).

China's financial institutions were merely established in the late 1970s. People's Bank of China was separated from Ministry of Finance in 1978 and soon designated as central bank. The government re-established the Agriculture Bank of China, the Bank of China, and the China Construction Bank and set up the Industrial and Commercial Bank in the same period to take over the lending responsibilities of mono-banking system. Although the effort had been made to improve profit incentives of the aforementioned four state-owned banks and quality of their portfolios, policy loans, mainly to state-owned enterprises, still accounted for a significant proportion of their lending till the early 1990s (Park and Sehrt, 2001). Because of the policy lending to loss-making SOEs, a significant amount of the non-performing loans were accumulated in the four state-owned banks, which accounted for about 26 percent of total outstanding loans in 2001. Furthermore, the average capital ratios of the four state-owned banks, which were 7 percent in 2001, were lower than the Bank for International Settlements minimum of 8 percent (Deutsche Bank Research, 2002).

To reform the fragile banking system in China which is largely composed by the four state-owned banks, the government implemented a set of measures since the late 1990s. In 1999 and 2000, 169 Billion US Dollars non-performing debts of the state-owned banks were transferred to asset-management companies. In April 2003, China Banking Regulatory Commission was established to assume the supervisory responsibility that was previously performed by the central bank. The state-owned banks were required to strengthen credit assessment and loan recovery. Moreover, a consensus of reforming the four state-owned banks through listing them in stock markets was formulated among policy stakeholders. It was expected that after Initial Public Offering (IPO), the banks would be able to raise capital, diversify the ownership structure and improve management and governance under the pressure of financial market.

To execute the strategy, the central bank lent 45 billion US Dollars of its foreign exchange reserves to recapitalize two of four major state-owned banks, i.e. the Bank of China and the China Construction Bank. The capital injection lifted up the capital asset ratio of the Bank of China from 7 percent in 2002 to 8.6 percent in 2004 and the ratio of the China Construction Bank from 6.5 percent to 9.4 percent. In addition, the two banks' non-performing loan ratios were drawn down from 6.3 percent and 9.3 percent to 5.1 percent and 3.7 percent, respectively in the same two years period (Leung and Chan, 2006). The capital injection was an important step as part of a broader strategy for the reform of state-owned banks, which finally led to the successful Initial Public Offering of the China Construction Bank in Hong Kong stock market in October 2005 and the public listing of the Bank of China in May of 2006. The reform model of these two banks provided a solution example for the biggest state-owned bank, Industrial and Commercial Bank of China, which was public listed in October of 2006, and also for the Agriculture Bank of China.

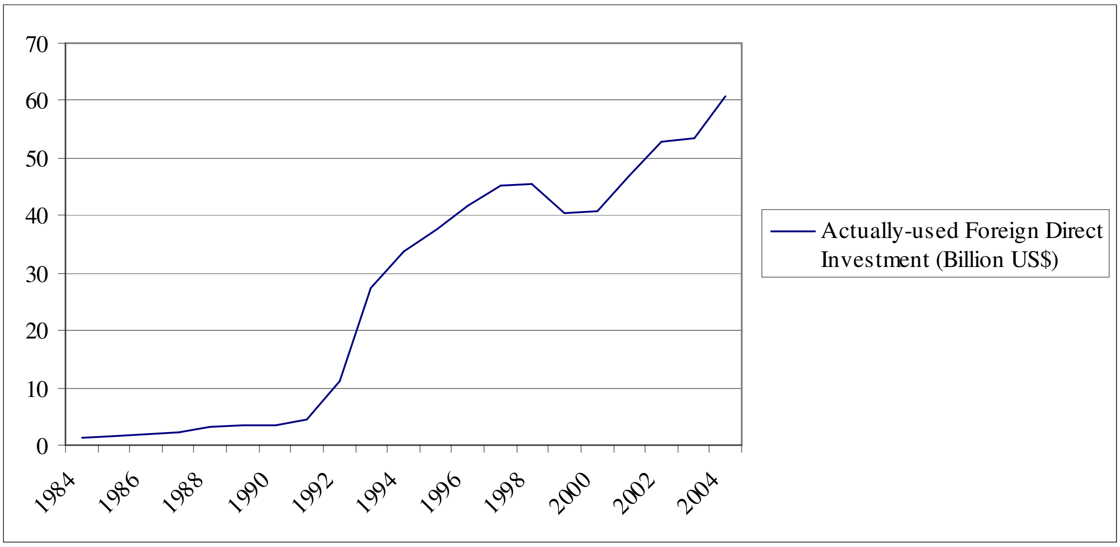
2.3 Policies Integrating China into the World's Economy

In order to welcome foreign investors, Chinese government in the 1980s set up five special economic zones, namely Shenzhen, Zhuhai, Xiamen, Shantou, Hainan to encourage overseas Chinese's investment. A lot of favorable policies, including tax and non-tax incentives, were enacted by central and local governments to facilitate foreign investors to establish companies in the special economic zones (Wei, 2003). The business income tax rate for the foreign firms located in the zones was merely 15 percent, compared to 33 percent for domestic firms. In addition, these taxes were not levied during the first two years of operation (Branstetter and Feenstra, 2002). China' huge market, governments' favorable Foreign Direct Investment (FDI) policy, low cost for manufacturing constituted the centripetal force to attract the inward FDI to China. Hence, China's inward FDI grew rather steadily from 1.26 Billion US Dollars in 1984 to 4.37 Billion US Dollars in 1991. After the government took a firmer stand to court foreign investment in 1992, FDI inflow jumped to 11.01 Billion US Dollars and has increased drastically since then. In 2004, China received 60.63 billion US Dollars FDI (Figure 2.3) and continued to be the most popular FDI destination among the developing countries.

Beyond welcoming FDI, Chinese government also took measures to dismantle the planned foreign trade system. The trading rights were expanded to a large number of state-owned companies and further to foreign and private companies. The number of commodities of which the trading rights were limited to state-owned trading companies was reduced. At the end of 1981, the 10 largest state-owned foreign trade corporations managed 76.6 percent of the Chinese exports and 81.3 percent of imports, but their shares dropped to 10 percent and 16.9 percent in 1992, respectively (Lin and Schramm, 2003). The statutory tariff rates were reduced significantly since the 1980s (Table 2.2), which promoted technological transfer in China by facilitating importing advanced machinery and equipment. More importantly, an open economy environment was created by the tariff reduction, which is critical for nurturing the competitiveness of domestic firms.

To attract foreign investors to manufacture in China, Chinese government provided foreign exchange on favorable terms, tax concessions and easy access to domestic raw materials to the firms engaging in the business of assembling imported parts and components and re-exporting final products. Laws and regulations with regard to foreign investment were formulated to protect foreign investors' assets, profit and legitimate rights. These measures promoted rapid expansion of export processing business in China. After China entered WTO in 2001, China has been further integrated into global production networks of multinational corporations, indicated by the export and import volume surge after 2001 (Figure 2.4). Many producers in high income economies, particularly in East Asia, such as Japan, South Korea and Taiwan, outsourced their manufacturing business or transferred their production departments to China in order to retain market share in the keen global competition. According to China's Ministry of Commerce's report, the share of processing trade export accounted for 55 percent of China's total export in 2004 (Xinhua Net, 2004).

Figure 2.3: Inward Foreign Direct Investment in China



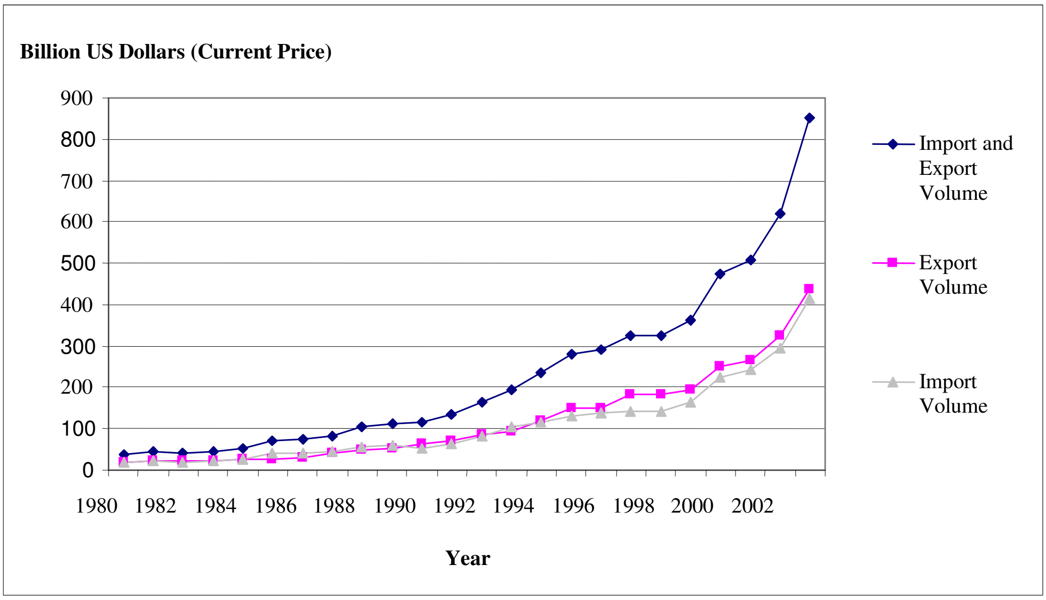
Source: Various issues of *China Statistical Yearbook*.

Table 2.2: Average Statutory Import Tariff Rate and Chinese Domestic Companies Authorized to Conduct Foreign Trade: 1978-2001

Year	Average Statutory Import Tariff Rate	Chinese Domestic Companies Authorized to Conduct Foreign Trade
1978	N.A.	12
1982	55.6	N.A.
1985	43.3	800
1986	N.A.	1200
1988	43.7	5000
1991	44.1	N.A.
1992	43.2	N.A.
1993	39.9	N.A.
1994	35.9	N.A.
1996	23.0	12000
1997	17.0	15000
1998	N.A.	23000
1999	N.A.	29258
2000	16.4	31000
2001	15.3	35000

Source: Lardy (2002).

Figure 2.4: The Growth of China's Export and Import Volume since 1980



Source: Various issues of *China Statistical Yearbook.*

To sum up, the gradual transformation of the Chinese economy in the past two decades started from the rural area and then expanded to the industry sector. The reform overhauled the economic institutions at micro- and macro-level. Market oriented economic system has been established to govern the country's economy, though lasting effort is still needed to transform the remaining planned institution and improve the efficiency of the current system. The reform and transformation significantly enhanced the productivity of the firms in the country and strengthened their competitiveness in the global market. They constitute the backdrops of the issues that we study and analyze in the following chapters.

Chapter 3 Organization, Program, and Structure: An Analysis of the Chinese Innovation Policy Framework[1]

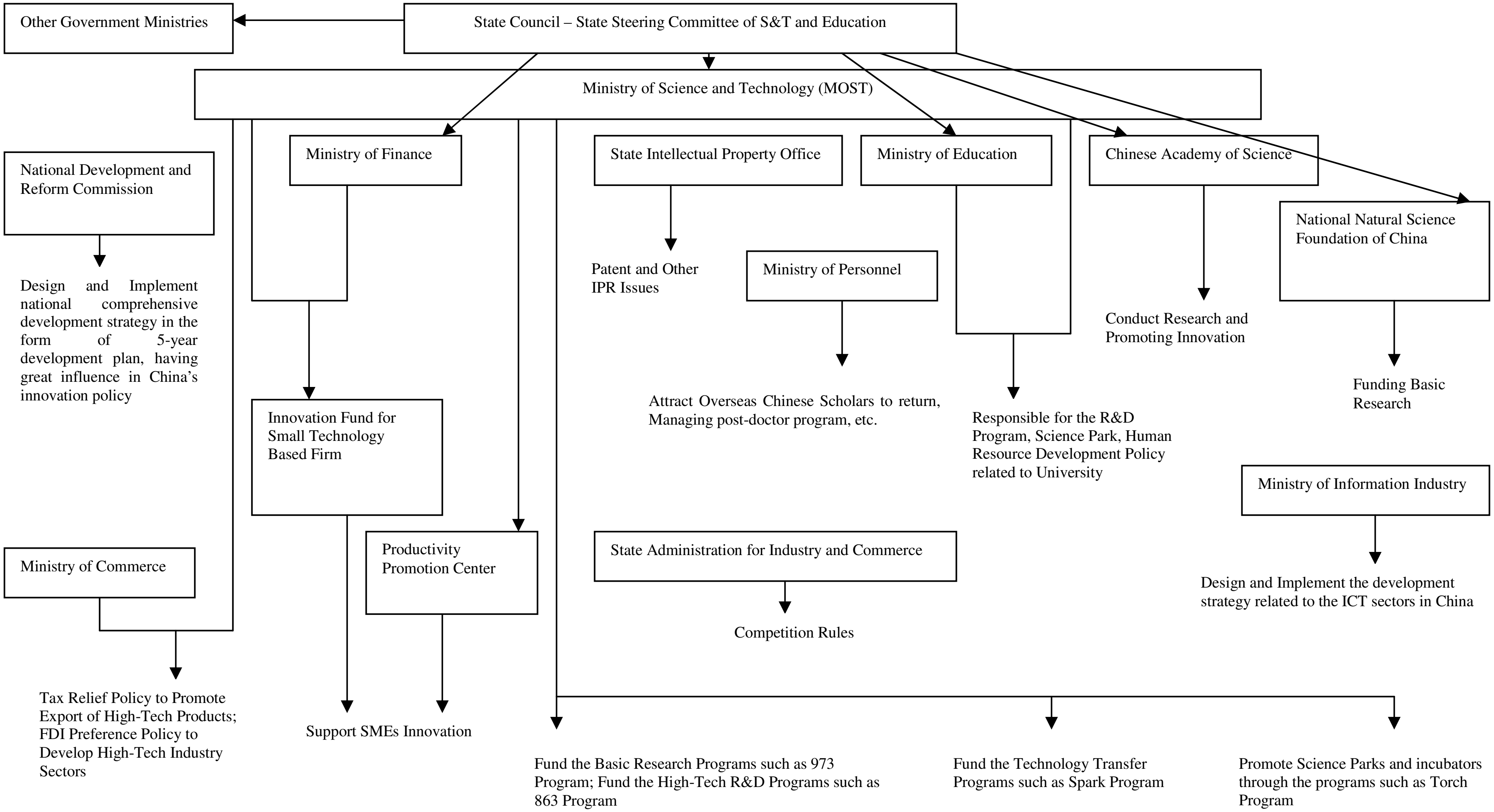
In this chapter, innovation policy is defined as a set of policy actions aiming to raise the quantity and efficiency of innovative activities. “Innovative activities” refers to the creation, adaptation and adoption of new or improved products, processes, or services (European Commission, 2000). Highlighted in the “National Innovation System” theory (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Edquist, 1997), a country’s innovation performance is largely determined by the policy which fosters creation, transfer and absorption of technology, knowledge and skills in industry and S&T organizations. It also depends on the policy influencing the interplay between these two sectors. The innovation policy can be developed and implemented at the local, regional, and national levels. The Chinese innovation policies, which are addressed in this chapter, are mainly established and executed by the Chinese central government at the national level.

3.1 The Governance Models of Innovation Policy Matters in China and OECD Countries

After 1978, the basic principles of market-oriented economy were introduced into China’s S&T policy reform. China’s S&T and innovation system experienced a series of multi-level administration reforms in combination with shifts in administrative power between different government bodies and agencies (US Embassy Beijing, 2002; OECD, 2002; Sociedade Portuguesa de Inovacao, 2002). The main executive stakeholders with regard to the Chinese innovation policy framework are shown in Figure 3.1.

[1] This chapter is adapted from the article Huang, Can; Amorim, Celeste; Spinoglio, Mark; Gouveia, Borges; Medina, Augusto, 2004. Organization, Program and Structure: An Analysis of the Chinese Innovation Policy Framework. *R&D Management*, 34, 4, 367-387.

Figure 3.1: Chinese Innovation Policy Institutions



In the Chinese innovation system, there exists a coordination mechanism in the State Council, called the State (National) Steering Committee of S&T and Education (*Guo Wu Yuan Ke Ji Jiao Yu Ling Dao Xiao Zu*), founded in 1998, which is the highest ranked innovation policy coordination body in China. The State Council Premier plays a role of coordinator for national strategy of S&T and education. From June 2003, the group had been leading in designing and developing an outline document "2006-2020 Chinese National Science and Technology Development Strategy", which was announced finally in March 2006. Compared with the Chinese structure, the co-ordination structure at ministerial level with the similar task can be found in the OECD countries, for example in Finland. The Finish Science & Technology Council, chaired by the Prime Minister is composed of seven Ministers and ten representative organizations (European Commission, 2001a).

In 1998 the State Science and Technology Commission changed its name to the Ministry of Science and Technology (MOST) and became a principal propeller in China's technological endeavors. Now, MOST is regarded in China as having a high competence with regard to the design and implementation of innovation policy. Through its executive body, it implements several programs to fund basic and applied R&D, serve enterprises, especially SMEs to innovate, manage and promote the science parks and incubators throughout China and develop human resources in the S&T field.

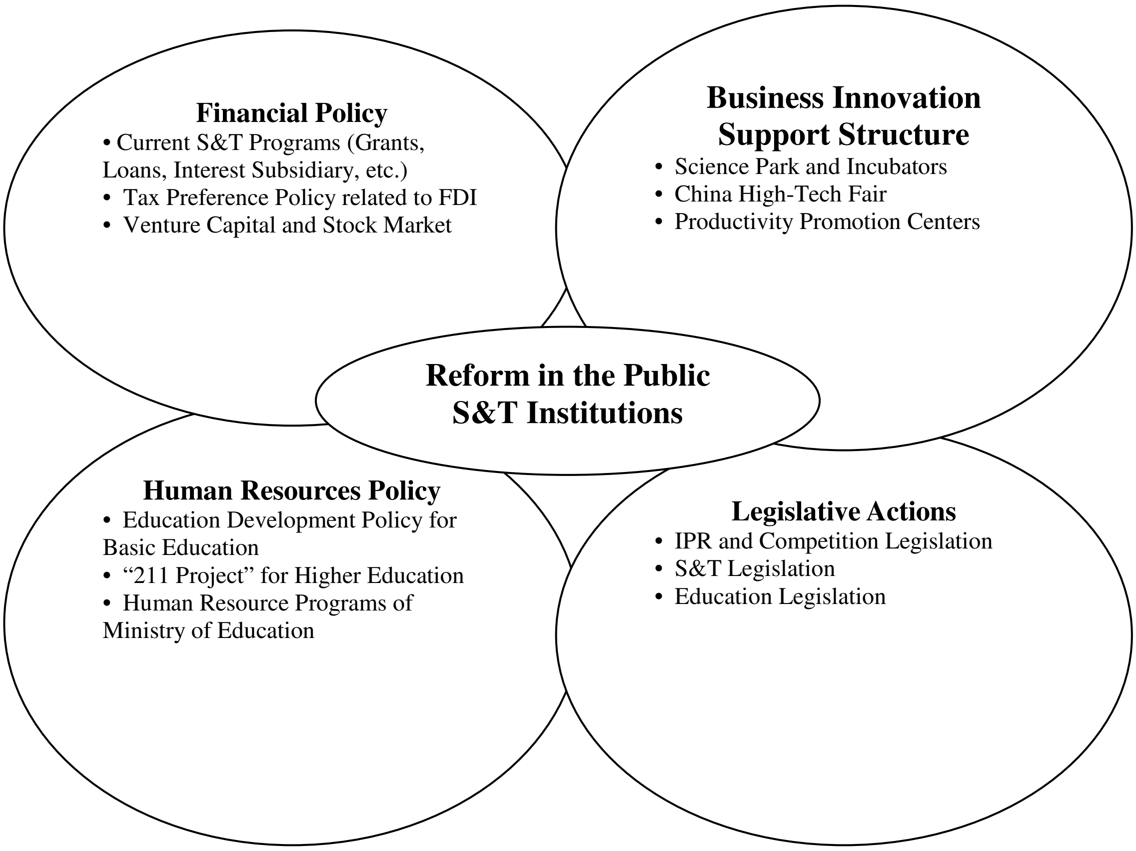
Models of governance differ among the OECD countries. In some countries, there is no separation between the government departments that design policy and those that implement measures. For instance, in the UK, the Department of Trade and Industry is at the center of innovation governance system. It designs science policy and also "operates and/or funds a number of schemes for the promotion of innovation in companies" (European Commission, 2002a), which is very similar to China's governance system. Differently, in countries like Ireland, policy is framed by ministries but delivered by semi-autonomous agencies. There is a distinction between the responsibilities of the Department of Enterprise, Trade and Employment and Enterprise Ireland, which is the implementing agency (European Commission, 2002b). In Austria, Belgium, Germany, Spain, the countries with federal structure, innovation policy framework is more complex with the interaction of federal and local governments (European Commission, 2002c).

The Chinese Academy of Science is another important stakeholder in the Chinese innovation policy framework. It has been an essential part of China's S&T system in the planned economy, founded in 1949 by following the Soviet Union's model. After the years' reform and restructuring, by the end of 2002 it still had a huge size, composed of 112 institutes, including 84 scientific research institutes, one university, one graduate school and 4 documentation and information centers and two media and publishing organizations (Chinese Academy of Science, 2002a). Distributed over various parts of the country, the Chinese Academy of Science had a total staff of over 45,600 of whom 67.2 percent are scientific personnel (Chinese Academy of Science, 2002b). The statistical data show that the Chinese Academy of Science is the major beneficiary of China's governmental S&T funding. In 2002 it received 20 percent of total funding of National Nature Foundation of China and conducted 12 of a total of 26 projects of Program 973; in 2001 and 2002, it received 14.1 percent of total funding of Program 863 (Chinese Academy of Science, 2002c). (The S&T programs in China are discussed in section 3.2.2)

3.2 The Policy Actions Implemented in China for Promoting Innovation

Through the "National Innovation System" approach, some scholars endeavored to create a theoretical scheme to compare the different national innovation systems in the diversified social and economic context (Nelson, 1993; Edquist, 1997; Liu and White, 2000; Shyu et al., 2001; Chang and Shih, 2004). However, the collected literature has not provided a comparative framework for describing the Chinese innovation policies in transition, which miss some typical policy components of the systems in the established market economies, but at the same time possesses the others inherited from planned economy. Particularly, the literature does not provide insight into the question such as in which area the Chinese policy has been catching up with international advanced level and in which area it is still weak. Therefore, we propose an analytical scheme for China's innovation policy framework and examine each policy category respectively (Figure 3.2).

Figure 3.2: Chinese Innovation Policy Framework



3.2.1 Reform of the Public S&T Institutions

Similarly to the transformation taking place in China, the reform of public S&T systems also occurred in the post-socialist central and eastern European countries (Dyker and Radosevic, 1999). To transform the R&D system highly detached from industry and to strengthen the industrial innovation capability are the tasks that these countries needed to accomplish in the transformation. Gokhberg (1999) summarizes the policy chosen by the central and eastern European countries during the transitional period such as increasing government's funding for R&D, maintaining and developing the basic research and improving the collaboration between S&T institutions, universities and industry etc.

The similar policy measures were also implemented in China. Gu (1995) discusses intensively the policy reform of the S&T System in China by dividing the evolution of the reform policy into several phases. Suttmeier and Cao (1999), Liu and White (2001), Liu and Jiang (2001) and Cao (2002) extend the observation of policy initiative to cover the period after 1995. However, the analysis on the newest round reform since 1999, called "the transformation of the R&D institutes", has not been analyzed intensively in the published literature. In Table 3.1 and 3.2, we synthesize the above works and the result of the survey done by MOST in 2002 May on the 290 newly transformed R&D institutions, depicting a preliminary picture of China's latest reform of public S&T institutions after 1999.

3.2.2 Financial Policy

Starting in the 1980s, China's government intensively utilized a series of programs with different objectives to fund S&T activities. The initial time, priorities and characteristics of these programs are discussed in Table 3.3. The growing budgets of these programs demonstrate that China's government was persistently committed to the financial support to S&T and R&D activities (Table 3.4). Furthermore, the central government set up its strategy of attracting the financial input from local governments and enterprises to co-fund the S&T program. A typical case is Spark Program. The funding of Spark Program was mainly from the bank loan and the own capital of enterprises. Since 1990 the government appropriation for this program had hardly surpassed 5 percent. In 2004, the 863 Program, Key Technology R&D Program and 973 Program emerged as the biggest three funding programs led by MOST, accounting for 72 percent of the R&D funding managed by MOST.[2]

[2] National Natural Science Foundation of China is independent from MOST and reports directly to State Council.

Table 3.1: Chinese Reform Policy for Public S&T Institutions: 1978-2004

Period	Objectives of Policy Actions	Policy Actions
Reformation of Planning Practice (1978-1984)	Recover and develop the R&D system and integrate it into the planned economic practices.	• Rehabilitation and improvement of R&D institutions in the post-Culture Revolution (1966-1976) period; • Integration of R&D activities into the 6th National Five-Year Plan (1980-1985).
Performing S&T activities in the "Market" (1985-1991)	Establish the horizontal cooperation between S&T sector and enterprises.	• Replace the planned S&T funding mechanism with the merit-based project competition mechanism; • Reduce fiscal appropriation to R&D institution to force them to cooperate with industry; • Create a "Technology Market" to legitimize transactions of technology transfer and set up the agencies to promote technology transfer; • Enhance the autonomy of R&D institutions and mobility of the S&T Personnel; • Attempt to merge the R&D institutions into enterprises; • Support the spin-off enterprises.
Integrating S&T activities into " Socialist Market Economy" (1992-1998)	Run non-basic research R&D institutions as run enterprises.	• Endow the R&D institutions the comprehensive economic autonomy as the same hold by enterprises; • Encourage spin-off activities through developing science parks and incubators; • merge the R&D institutions into enterprises.
Large Scale Transformation of R&D institutions (1999 till now)	Transform nearly all of the government-owned R&D institutions.	• Transform the R&D institutions into enterprises, non-profit organizations, intermediary organizations or merge them into universities.

Source: Gu (1995); Suttmeier and Cao (1999); Liu and White (2001); Liu and Jiang (2001); Cao (2002).

Table 3.2: Transformation of Public R&D Institutions in China After 1999

Transformation Year	Number of Transformed R&D Institutions	Owners of the Transformed R&D Institutions	Status After Transformation	Preliminary Result of the MOST Survey in May, 2002 on 290 Transformed R&D Institutions
1999	242	Former State Economy and Trade Commission	Enterprises	• Revenue in 2001: 1.5 times of in 1999; Profit in 2001: 2.6 times of in 1999; Tax in 2001: 1.9 times of in 1999. • R&D expenditure annual growth rate in 2001: 16.2 percent; in 2000: 6.84 percent. • Patent application annual growth rate in 2001: 9.6 percent. • Employee average compensation in 2001: 142.6 percent of that in 1999. • 92.6 percent of them set up enterprises accounting system; 88.65 percent entered the local unemployment insurance; over 10 of them went public in the stock market.
2000	134	11 Ministries: Ministry of Construction etc.		
1999 - 2002	660	Local Governments		
2001	98	4 Ministries and Agencies: Ministry of Land and Resources etc.	89 institutions: Non-profit Organizations 61 institutions: Enterprises Others: Merged into universities, transformed into intermediary organizations	N/A
2002	107	9 Ministries and Agencies: Ministry of Agriculture etc.		
2004	43	5 Ministries and Agencies: Ministry of Health etc.		

Source: Li (2002).

Table 3.3: China's Current S&T Programs

Program	Initiating Year	Objectives	Characteristics of the Programs
Key Technology R&D Program *(Gong Guan Ji Hua)*	1983	Concentrate resources on developing critical technologies that are directly used in industrial development.	The program objective set in the 10^{th} five-year plan (2001-2005) is: 1) By 2005 the agriculture technology only lags behind international advanced level 5 years; 2) The technology of several key industry sectors such as ICT sector matches the level of developed countries of the mid of 1990s; 3) Develop technology related to environment protection and sustainable development; 4) Support enterprises to become the center of technological innovation.
State Key Laboratories Program *(Guo Jia Zhong Dian Shi Yan Shi Ji Hua)*	1984	Support laboratories in public or private institutions.	This program intends to promote the research and advanced training in the 159 laboratories (2002 data) affiliated to universities and R&D institutions. It also supports a number of national engineering research centers.
Spark Program *(Huo Ju ji Hua)*	1986	Support technology transfer in rural area and promote the rural area development.	In 1990s the government appropriation hardly surpassed 5% of the budget of the program. The bank loan and the own capital of the enterprise accounted for the major investment of the projects. The projects sponsored by this program obtained the government credit for the bank loan application. In 2000, 16.8 percent of total investment of this program came from bank loans.
National Natural Science Foundation of China (NSFC) *(Guo Jia Zi Ran Ke Xue Ji Jin)*	1986	Fund basic science research projects	From its establishment in 1986 to 2000, the NSFC has funded over 52,000 research projects in various categories by investing a total sum of RMB 6.6 billion. More than 60,000 scientists are supported by NSFC to conduct basic research. In 2004, the NSFC received over 40,000 project applications.
High Technology R&D Program (863 Program) *(863 Ji Hua)*	1986	Enhance China's international competitiveness and improve China's overall capability of R&D in high technology field.	The Program is dedicated to both civilian and military R&D. This Program is co-managed by MOST and Commission of S&T and Industry for National Defense. The Program covers 20 subjects in eight priority areas: Biotechnology, Information, Automation, Energy, Advanced Materials, Marine, and Space and Laser. In recent years, 863 program strengthened the funding to the projects conducted in industry.

Table 3.3 (Continued)

National New Product Program *(Guo Jia Zhong Dian Xin Chan Pin Ji Hua)*	1988	Compile annually the list of new and high technology product and support the development of those products through grants and subsidiary to loan interest.	In 2002, 71.86 percent of the program's funding was allocated through grants and 28.14 percent was through loan interest subsidiary.
Torch Program *(Huo Ju Ji Hua)*	1988	Support high technology industry sector development through setting up science park and incubator, fund research projects and promote human resource training etc.	By the end of 2003, through Torch Program the governments had established numbers of science park, incubator, software park, university science park etc. Inside these science parks and incubators, 28,504 high technology enterprises had received fund from the program and 3.49 million jobs had been created. The program had funded 10,261 projects.
Key Basic Science R&D Program (973 Program) *(973 Ji Hua)*	1997	Support basic science research.	The 973 Program is to support basic science research in the scientific areas such as agriculture, energy resources, information, resources & environment, and population & health; to foster human resource; and to establish a number of high caliber scientific research units.
The Innovation Fund for Small Technology Based Firms (IFSTBF) *(Ke Ji Xing Zhong Xiao Qi Ye Chuang Xin Ji Jin)*	1999	Support the establishment of Newly Technology Based Firms.	The financial support includes loan interest subsidiary, grants and capital investment. The fund facilitates the technology transfer from the R&D projects funded by Key Technology R&D Program, 863 program and Torch Program.

Source: Key Technology R&D Program (2004a, 2004b), National Key Laboratories Program (2004), Spark Program (2004), National Science Foundation of China (2004a, 2004b, 2004c), 863 Program (2004); National New Product Program (2004), Torch Program (2004), 973 Program (2004); Innovation Fund for Small Technology Based Firms (2004).

Table 3.4: The Funding of Current Chinese S&T Program: 1996-2004 (Billion RMB)[1]

	1996	1997	1998	1999	2000	2001	2002	2003	2004[3]	Ratio of Funding in 2000 to Gross Expenditure on R&D (Percentage)[5]
Key Technology R&D Program	1.06[4]	1.06[4]	1.06[4]	1.06[4]	1.06[4]	1.545[4]	1.545[4]	N/A	1.5	1.18
National Key Laboratories Program	N/A	N/A	N/A	N/A	1.542	1.737	2.212	N/A	N/A	1.72
Spark Program	28.804	35.754	34.008	38.43	48.213	N/A	N/A	N/A	N/A	53.83
National Science Foundation of China	0.646	0.777	0.889	1.084	1.284	1.598	1.968	N/A	2.246	1.43
863 Program[2]	0.45	0.65	0.67	0.8	0.9	Over 2	Over 4	N/A	5.5	1.00
National New Product Program	N/A	N/A	0.135	0.14	0.14	0.14	0.1386	N/A	N/A	0.16
973 Program	Not Start	0.625[4]	0.625[4]	0.625[4]	0.625[4]	N/A	N/A	N/A	0.9	0.70
The Innovation Fund for Small Technology Based Firms	Not Start	Not Start	Not Start	0.816	0.695	0.8	0.5	NA	NA	0.78

Source: Key Technology R&D Program (2004a, 2004b), National Key Laboratories Program (2004), Spark Program (2004), National Science Foundation of China (2004a, 2004b, 2004c), 863 Program (2004); National New Product Program (2004), Torch Program (2004), 973 Program (2004); Innovation Fund for Small Technology Based Firms (2004).

Note: 1. The data of Key Technology R&D Program, National Science Foundation of China, National New Product Program and 973 Program only include the funding from central government's appropriation. Differently, the data for State Key Laboratories Program and 863 program include the fund from local government and enterprises. The funding of Spark Program is mainly from the bank loan and the own capital of enterprises. Since 1990 the government appropriation has hardly surpassed 5% of the budget of the program.

2. The data for 863 Program are estimated by authors based on the various annual reports of the program. The 2001 funding in 2002 Annual Report was over 2 billion RMB, however, in 2001 Annual Report appeared to be 1.7 billion RMB.

3. Source of 2004 data: Ministry of Science and Technology (2004).

4. The annual averages are calculated by the authors by simply dividing the aggregate data. The central government appropriated 5.3 billion RMB and 3.09 billion RMB to Key Technology R&D Program in the period of 1996-2000 and 2001-2002, respectively. The central government appropriated 2.5 billion RMB to 973 Program from 1997 to 2000.

5. The data of GDP (2000) are from in *China Statistical Yearbook 2002* and the data of GERD (2000) are from *China Statistical Yearbook on Science and Technology 2002*.

The success of Chinese economic reform and the growth of the national innovation capability since 1978 can be partly attributed to the policy of welcoming foreign direct investment (FDI) (Liu and Wang, 2003; Buckley et al., 2002). China attracted FDI by providing physical and institutional infrastructures, as well as fiscal incentives. In 2002 China became the world’s largest recipient of FDI, receiving nearly 53 billion US Dollars (OECD, 2003a). The Chinese central government continuously implements tax advantage and deduction policies targeting foreign investors, but gradually shifts the focus of preference fiscal policy from low-tech and labor-intensive industry to high-tech manufacture and service sectors. For example, in July 2003 MOST and the Ministry of Commerce developed a list of favorable high-tech products that China’s governments encouraged FDI to produce in China.

China aimed to establish a viable financial system, and particularly a venture capital system, to support technology-based Small and Medium Enterprises (SMEs). Currently in China, there does not exist a specific law to regulate venture capital development. Legislative framework for venture capital only consists of Company Law and a joint regulation of seven ministries. Some legislative proposals for venture capital law have been submitted to the national legislation authority, and at the local level, for example, the Shenzhen, Chongqing, Shenyang municipal governments have enacted some local regulations to protect and promote venture capital development in their administrative areas.

The Chinese stock market is acting in support of high technology companies listed on the market. By August 1999, 17.8 percent of the listed companies had been high-technology companies. These companies had raised nearly 47.8 billion RMB (5.76 billion US Dollars).[3] Compared with those of ordinary listed companies, their average earnings per share and returns on equity were 64 percent and 45.5 percent higher, respectively (Zhou, 1999). After a long time debate whether it is viable to establish Chinese Nasdaq, China established Small and Medium Enterprise Board in Shenzhen stock exchange market in May 2004. By September of 2006, there had been 71 enterprises listed in the board.

[3] In this chapter, the exchange rate of US Dollars to RMB for the period of 1996-2004 is 1:8.3.

3.2.3 Business Innovation Support Structure

The internationally prevalent business support structures such as science parks and incubators also exist in China. By 2002, at the national level alone over 400 business incubators and 53 high-technology development zones had been developed through governmental support, mainly through Torch Program.[4] China's science park and development zones played a critical role in developing the Chinese high-technology sectors and building up the manufacturing sector's competitiveness. According to the data of Torch Program, the output of the 53 high-technology development zones in 2001 accounted for 82.5 percent of total high-tech product output and around 12 percent of gross manufacturing output in the country (See Table 3.5). In 2002, there were 3.49 million employees hired by the enterprises in those zones; the expenditure on R&D spent by theses enterprises reached 31.47 billion RMB (3.79 billion US Dollars), that is, 24.4 percent of gross expenditure on R&D (GERD) in China and 40 percent of business expenditure on R&D (BERD)(Ministry of Science and Technology, 2003).

As an intermediary event, China Hi-Tech Fair (CHTF) received strong support from the central government to link the Chinese and overseas high-tech industry sectors. Since 1999, the fair has been hold every fall in Shenzhen. It was jointly hosted by the Ministry of Commerce, MOST, Ministry of Information Industry, National Development and Reform Commission, Chinese Academy of Sciences and the Shenzhen Municipal People's Government. The companies from 42 countries attended the 2003 session. The transaction value of the contracts singed in CHTF reached 12.84 billion US Dollars in that session (China Hi-Tech Fair, 2003). CHTF has also attracted the active participation of overseas Chinese students. This large pool of overseas Chinese students brought back capital and high-tech technology to set up start-ups in China. CHTF acted as a platform to facilitate them to study the market, meet potential investors and gain the support from various levels of governmental agencies.

[4] The name of high-technology development zones is translated exactly from Chinese, actually they could be referred as science parks.

Table 3.5: Development of the Chinese Science Parks and Incubators[1]

	1991	1992	1992	1994	1995	1996	1997	1998	1999	2000	2001	2002
Industrial Output of the Enterprises in the 53 National High-technology Zones (Billion RMB, Current Price)[1]	7.12	18.68	44.73	85.27	140.28	214.23	310.92	433.36	594.36	794.2	1011.68	1293.71
Output of High-Technology Sectors in China (Billion RMB, Current Price)[1,2]					409.8	490.9	597.2	711.1	821.7	1041.1	1226.3	
Output of Manufacturing Sectors in China (Billion RMB, Current Price)[1,2]					4870	5130.1	5998.5	5966.8	6395.4	7510.8	8442.1	
Ratio of Output of the Enterprises in the 53 National High-technology Zones to Output of High Technology Sectors in China (Percentage)					34.23	43.64	52.06	60.94	72.33	76.28	82.50	
Ratio of Output of the Enterprises in the 53 National High-technology Zones to Output of Manufacturing Sectors in China (Percentage)					2.88	4.18	5.18	7.26	9.29	10.57	11.98	
Number of Incubator	43	61	61	73	73	90	100	77	110	131	280	436
Number of Tenants	500	1013	1500	1390	1854	2476	2670	4138	5293	7693	12821	23373
Number of Graduated Tenants				190	364	648	825	1316	1934	2770	3994	6927

Note:1. Source: Torch Program (2004).
2. Source: *China Statistics Yearbook on High Technology Industry 2002.*

Established after 1992, Productivity Promotion Centers (PCCs) in China are considered as a group of intermediary and consulting organizations to support innovation in the business sector. In 2002, there are 865 PCCs under the administration of provincial, municipal, county government and industry sector administrative departments. Their service includes consulting, technology promotion, products testing, information collecting, human resource, training and incubation, etc (Chinese Association of Productivity Promotion Centers, 2003).

3.2.4 Strengthening Human Resources Measures

With the economic development and the growth of fiscal revenue, the Chinese government could leverage more resource to promote the development of the education system. The average years of schooling of the population aged 15-64 increased from 4.10 years in 1980 to 5.96 years in 2000 (Cohen and Soto, 2001). In 1980, only 15 percent of population finished junior secondary education, 6 percent concluded senior secondary education and 1 percent received higher education. In 2002, the proportions were increased to 34 percent for junior secondary education, 11 percent for senior secondary education and 4 percent for higher education, respectively (Hu, 2003). In 2000, gross entry rate of primary education, junior secondary education and senior secondary education reached 99.1 percent, 88.6 percent and 42.8 percent, respectively (Li, 2001). Nevertheless, rural education remains a serious challenge and the country is still confronted with the problem of 85.07 million illiterate people, of which 20 million are at an age between 15 and 50 (People Daily, 2002).

Ministry of Education in China recently issued “The 2003-2007 Action Plan for Invigorating Education”, setting the new-round targets for the country’s education development. Listed in the action plan, the proportion of children in the relatively poor western region finishing nine-year compulsory education would reach 85 percent by 2007.[5] The illiterate rate of young people would decrease to 5 percent and the children from rural poor family would be exempted from tuition fee and book fee. Boosted by relatively larger amount of higher education investment (World Bank, 2003)[6], the Chinese universities have achieved extraordinary development in recent years. A

[5] The west region is composed of 12 provinces and is the home of 28.7 percent of the country’s habitants.
[6] The ratio of China’s government per-student spending on tertiary, secondary and primary education was 10:2:1 in the 1990s. This ratio was higher than the those of the US, Korea, Chile and Mexico.

program titled "211 Project" was implemented in 1995 by the central and local governments with a goal of developing 100 key universities in China. By 2000, the total investment of this project had reached 18.3 billion RMB (2.20 billion US Dollars) (Ministry of Education, 2003a).

The Ministry of Education cooperates with some funding organizations to develop a series of programs to recruit overseas talents to work in China. Figure 3.3 describes the objectives of the programs. The Cheung Kong Scholars Program was jointly established by the Ministry of Education and Li Ka Shing Foundation.[7] During the first phase of the program, they each contributed 60 million US Dollars to establish 300 to 500 professorships by special appointment at tertiary institutions within three to five years. Phase two would see the number of professorships increased to 1,000. The professors funded by this program would receive a special stipend of 100,000 RMB (12,048 US Dollars) in addition to the regular remuneration package offered by universities in accordance with state guidelines (Ministry of Education, 2003b).

3.2.5 Legislative Actions

Given the fact that China's legal environment did not start to evolve until the late 1970s (Law, 2002), the evolution of China's legal system has been rapid and the progress is undoubtedly significant. Over the past years, China has launched the comprehensive reform of legislation system, enacting a series of laws regarding innovation, competition and intellectual property right protection. The landmark legislation includes the Trademark Control Act (1963), US-China Agreement on Intellectual Property Protection (1979), Trademark Law (1982, revised in 1993), Patent Law (1984, revised in 1992), Copyright law (1990), Regulation on Computer Software Protection (1991), Unfair Competition Law (1993), Protecting Consumer's Rights and Interests Law (1993), Regulations on Anti-dumping and Anti-subsidization (1997) and Price Law (1998). In Addition, the General Principles of Civil Law (1986) and subsequent Civil Procedure Law (1991) recognize the legal right of Chinese citizens and domestic and foreign entities in terms of holding and protecting own IPR.

[7] Mr. Li Ka Shing is a Hong Kong-based entrepreneur. He set up the foundation to manage his charitable donations to education and medical care projects in Hong Kong and Mainland China.

Figure 3.3: Human Resource Programs of Ministry of Education

First Level	Cheung Kong Scholar Program *(Chang Jiang Xue Zhe Jiang Li Ji Hua)*		
Second Level	University Young Scholar Award *(Gao Xiao Qing Nian Jiao Shi Jiang)*	New Century Talents Training Program *(Kua Shi Ji You Xiu Ren Cai Pei Yang Ji Hua)*	
Third Level	Promising Young Scholar Funding Program *(You Xiu Qing Nian Jiao Shi Zi Zhu Ji Hua)*	University Key Scholar Funding Program *(Gao Deng Xue Xiao Gu Gan Jiao Shi Zi Zhu Ji Hua)*	Overseas Returnee Scientific Research Fund *(Liu Xue Hui Guo Ren Yuan Ke Yan Qi Dong Zi Jin)*

Source: Ministry of Education (2002).

As far as international legal cooperation, China was admitted as a member of World Intellectual Property Organization (WIPO) (1980); joined Paris Convention for Protection of Industrial Property (1984), Washington Treaty on Intellectual Property in Respect of Integrated Circuits (1989), Madrid Agreement Concerning the International Registration of Marks (1989), Berne Convention for Protection of Literary and Artistic Works (1992), Convention for the Protection of Producers of Phonograms Against Unauthorized Duplication of Their Phonograms (1993), Patent Cooperation Treaty (1993) (Oksenberg et al., 1996; State Council Press Office, 1994). China also cooperated frequently with WIPO and European Patent Office (EPO) for training personnel. The government promoted IPR teaching and research in over 70 universities. Nearly 20 cities or provinces have set up IPR courts and the training programs for judicial officials. China's rapid development in the IPR legislation has gained the praise from the international community, particularly from WIPO.

Promulgated in the last decade, Science and Technology Development Law (1993) regulating high-tech industry development, Agriculture Technology Transfer Law (1993), Strengthen Technology Transfer Law (1996), Dissemination of Science and Technology Knowledge Law (2002) and Small and Medium Enterprises Promotion Law (2002) demonstrate the efforts of the Chinese government in terms of legislation.

Since the 1980s, the Chinese legislative authority, i.e. National People’s Congress, passed six laws to form a legal framework regulating the education system. They are Regulations on Degrees (1980), Compulsory Education Law (1986), Teachers Law (1993), Education Law (1995), Vocation al Education Law (1996) and Higher Education Law (1998). In the same period, the central government issued hundreds of regulations and statutes to strengthen the reinforcement of these laws.

3.3 The Analysis of China’s Innovation Policy in the OECD context

In order to benchmark the performance of their members in S&T and innovation field, OECD and European Commission systematically analyze the innovation policy of their member states. “Trend Chart on Innovation in Europe” is a main program launched by the EU to benchmark the innovation practice in different countries. We utilize innovation policy classification in Trend Chart database to reveal the difference between Chinese and EU countries’ innovation policy practice (Table 3.6). We also extract the data from “OECD Science Technology Industry Scoreboard 2003” to compare quantitatively the Chinese and OECD’s innovation performance (Table 3.7).

Demonstrated in Table 3.6 and 3.7, in some areas China’s innovation policies are well designed, but in others few policies have been executed to complement the well functioned ones to enhance the country’s innovation performance. We focus on the Chinese innovation policies in two areas, namely education and human resources and intellectual property right protection, to examine the Chinese current practice with the comparison of the policies of the advanced OECD countries.

Table 3.6: Comparison of Innovation Policy in China and the European Union Member States

The EU Trend Chart Innovation Policy Classification System		Examples of Policy Practices in China
Policy Category	Policy Priority	
Fostering an Innovation Culture	Education and initial and further training	Regulations on Degrees (1980), Compulsory Education Law (1986), Teachers Law (1993), Education Law (1995), Vocation al Education Law (1996) and Higher Education Law (1998) demonstrated the Chinese government's legislative efforts since the 1980s. "211 Project" and series of award and training programs including Cheung Kong Scholars Program constituted the recent policy actions. However, the education and training in China were still insufficiently invested. The further discussion is seen in the section 3.3.1.
	Mobility of students, research workers and teachers	Policy was co-developed by Ministry of Education and Ministry of Personnel to support foreign experts to work in China, to attract overseas Chinese students and scholars to return, and to encourage the placement of Ph.D graduate for post doctoral research in enterprises.
	Raising the awareness of the larger public and involving those concerned	China's legislative authority passed Dissemination of Science and Technology Knowledge Law (2002). The government launched the tax preference policy for institutions whose main function is disseminating S&T knowledge. Grants were provided to fund the project of increasing public awareness of S&T.
	Fostering innovative organizational and management practices in enterprises	Not Available.
	Public authorities and support to innovation policy-makers	Not Available.
	Promotion of clustering and co-operation for innovation	Many of the strategies are developed by local governments. For example, the Shanghai municipal government cooperated with other neighboring provinces in the Yangtze river delta for coordinating the development of the industrial clusters in the region. The similar practice is found in the Pearl river delta region embracing Guangdong province, Hong Kong and Macau.

Table 3.6 (Continued)

Establishing a Framework conducive to Innovation	Competition	Enactment of Unfair Competition Law (1993), Protecting Consumer's Rights and Interests Law (1993) and Regulations on Anti-dumping and Anti-subsidization (1997), Price Law (1998) revealed the government's legislative efforts. However, the young competition policy regime needs to be improved and strengthened (Lin, 2003).
	Protection of intellectual and industrial property	MOST issued several regulations on IPR protection and exploitation. State Intellectual Property Office launched the projects to strengthen the public awareness of IPR protection. However, the IPR policy in China needs to be restructured and improved. The further discussion is seen in the section 3.3.2.
	Administrative simplification	The regulations of simplifying administration were launched to encourage creation of Newly Technology Based Firms and attract FDI.
	Amelioration of legal and regulatory environments	China's Legislative actions covered the field of IPR, S&T and education etc. The further discussion is seen in the section 3.2.5.
	Innovation financing	The Innovation Fund for Small Technology Based Firms was established.
	Taxation	Tax preference policy was implemented to provide incentive to create newly technology based firms and attract FDI. However, the current tax preference policy for encouraging innovation in the established enterprises did not achieve satisfying performance (Wu, 2003).
Gearing Research to Innovation	Strategic vision of research and development	The Chinese central government launched the "2006-2020 Chinese National Science and Technology Development Strategy" in March 2006.
	Strengthening research carried out by companies	Some tax preference policies specifically for some industry sectors were implemented, such as the policy encouraging investment in integrated circuit manufacture sector. However, the effect of this type of fiscal policy is weak according to Wu (2003). 863 Program increasingly supported industry R&D. In 2002, 30 percent of the projects financed by the program are implemented in the enterprises (863 Program, 2004).

Table 3.6 (Continued)

	Start-up of technology- based companies	Numerous policies aimed to promote science parks and incubators and attract overseas Chinese to set up start-up in China.
	Intensified co-operation between research, universities and companies	The Chinese government created a new type of agency titled "Technology Transfer Center" in 2003.
	Strengthening the ability of companies, particularly SMEs, to absorb technologies and know-how	Not Available.

Source: European Commission (2000b, 2001b, 2002d).

Table 3.7: Science and Technology Indicators for China and Selected OECD and non-OECD Countries

	China	Israel	Russian Federation	Singapore	EU 15	OECD Total	Italy	Japan	Poland	Sweden	US
Gross Expenditure on R&D (GERD) (Million Current PPP US Dollars)[1]	72076.8	6359.7	14190.4	2129.7	162813.3	578749.4	13556.5[2]	96532.3	2367.7	9232.7	252938.5
GERD as a Percentage of GDP[1]	1.29	4.73	1.24	2.19	1.93	2.33	1.07[2]	3.09	0.67	4.27	2.82
Total Researchers per Thousand Total Employment[1]	1.1	N/A	7.5	9.0	5.8[2]	6.5[2]	2.9[2]	10.2	3.8	10.6	8.6[3]
Percentage of GERD Financed by Industry[1]	57.6[2]	69.6[2]	32.9[2]	55.0[2]	56.2	63.6	43.0[4]	73.0	30.8	71.9	68.3
Percentage of GERD Financed by Government[1]	33.4[2]	24.7[2]	54.8[2]	40.3[2]	34.5	28.9	50.8[4]	18.5	64.8	21.0	26.9
Business Enterprises Expenditure on R&D BERD (Million Current PPP US Dollars) [1]	44099.2	4643.5	9915.7	1308.2	105121.2	403243.6	7275.2	71119.1	848.4	7166.8	188122.8
BERD as a Percentage of GDP[1]	0.79	3.46	0.87	1.34	1.06[2]	1.48	0.43[4]	2.25	0.21	3.07	1.92
Number of "Triadic" Patent Families Per Million Population[5]	0.055	54.167	0.490	19.118	35.897	37.417	12.103	89.400	0.233	94.216	52.712
Number of Patents Applications to the EPO in the ICT Sector Per Million Population[5]	0.031	61.714	0.320	22.177	35.313	30.754	9.360	60.810	0.129	88.793	40.337
Number of Patents Applications to the EPO in the Biotechnology Sector Per Million Population[5]	0.008	11.739	0.095	2.294	5.341	5.153	1.042	4.691	0.052	7.456	9.634

Source: OECD (2003c).
Note: 1. The data for the non-OECD countries without the superscript are the year of 2002. The data for the OECD countries without superscript are the year of 2001.
2. The data are for 2000.
3. The data are for 1999.
4. The data are for 1997.
5. The data are calculated by the authors. The patent data are for 1998. The Data of Population (1998) except for EU 15 and OECD Average are from World Bank *World Development Indicators (WDI)* database Data Query. The data of EU 15 and OECD Average are from World Urbanization Prospects, the 2001 Revision, United Nations Population Division.

3.3.1 Education and Human Resources

China’s education reform since 1980s has been discussed comprehensively in the literature from the point of view of public policy (Kwong, 1996; Mok and Wat, 1998; Yang, 1998), finance (Tsang, 1996), and legislation (Law, 2002). The conclusions reached in these analyses are supported by empirical studies by Liu (2004) and even the official address of the Chinese leaders (Zhu, 2001). It is generally agreed that directed by the principle of “economic rationalism”, China’s education reform through the decentralization of finance structure and diversification of finance sources does not increase the lingering ratio of public education investment to total public expenditure. Moreover, the decentralization and diversification strategy in some degree gives rise to the unbalanced education development across eastern and western regions, also between urban and rural area. All of these, if last, will exacerbate the development of China’s human capital resource and limit the innovation performance in the long run.

The OECD countries are far ahead of China in the field of education and human resources development, either reflected by quantitative indicators or policy focus. Now the EU countries attach great importance to lifelong learning in order to keep pace with accelerating technological progress and technology-driven social change. To support human resource mobility between public research institutions and private sector companies, many OECD countries have adopted measures like temporary placements and industry-funded PhD projects. According to the analysis of OECD and UNESCO’ s World Education Indicators (WEI) Program (OECD and UNESCO Institutes for Statistics, 2000, 2001, 2003), China not only lags much behind the OECD countries’ average level in many indicators but also stays in an unfavorable situation compared with the participating developing countries (hereafter WEI countries), including Argentina, Brazil, Chile, Egypt, India, Indonesia, Jordan, Malaysia, Paraguay, Peru, Philippines, Russian Federation, Sri Lanka, Thailand, Tunisia, Uruguay, Zimbabwe (Table 3.8).

Table 3.8: China's Education Performance in World Education Indicators Program

	China's Performance	WEI Average	OECD Average	Ratio of China's Performance to WEI Average (Percentage)	Ratio of China's Performance to OECD Average (Percentage)
School Expectancy for a five-year-old Child (Year) (2000)	10.3	13.0	16.8	79.2	61.3
Gross Entry Rates to Upper Secondary Education (2000)	42%	64%	-	65.6	-
Entry Rates to Tertiary Education (2000)	14%	40%	60%	35.0	23.3
Average Years of Schooling in the Population Aged 15-64 (Years) (2000)	5.96	7.63	-	78.1	-
Public Expenditure on Educational as a Percentage of GDP (1999)	2.1	4.3	5.2	48.8	40.4
Proportion of Private Expenditure on Education Institutions (1999)	44.2%	28.3%	12%	156.2	368.3

Source: OECD and UNESCO Institutes for Statistics (2000, 2001, 2003).

As mentioned before, thanks to the Chinese government's effort in past decade, the education legislative system was already established in China. However, both government and non-government parties, including school, students and parents, frequently challenged these education law and regulations (Law, 2002). The "Decision on Education System Reform" announced in 1985 stipulates that the governments of various levels are obliged to maintain the growth of the investment to education. The growth of education expenditure of government at various levels is required to be faster than the growth of fiscal revenue. However, the growth rate of total education appropriation of central and local governments in 1996 and 1997 were still lower than that of budgetary revenue, even the obligation was reiterated in the subsequent policy documents such as "Strategy of China's Education Reform and Development" announced in 1993. From 1999 to 2001 the central government itself failed to fulfill this obligation (Table 3.9). In most of the years in 1990s, China's fiscal appropriation to education continuously grew with a lower rate compared with the growth of the budgetary revenue. This fact implies that the economic development in the past years in China does not proportionally benefit the country's education development and fails to diminish the gap between China and the world leading countries.

The gradually declining ratio of education appropriation of central governments to that of local government reveals that local governments assumed greater responsibility of education investment than before (Table 3.9). The crucial decisions such as whether invested in education, how much invested, in which area would invest: primary, secondary or tertiary education, depended much on local government's budget plan and the will of the local leadership. Inevitably, the regional and rural-urban discrepancy of education development was widened given that after the 1980s the economic growth rates varied to a great extent across different regions and also between rural and urban areas (Zhang, 2002; Wang, 2002).

Table 3.9: China's Budgetary Appropriation for Education in 1990s

	1991	1992	1993	1994	1995	1996	Data Breakdown	1997	1998	1999	2000	2001
Government Appropriation for Education Expenditure[1] (Million RMB)	45970	53870	64440	88400	102840	121190	Central Government	15707.73	19966.66	21539.61	21854.192	26655.68
							Local Government	120064.9	136592.51	160036.363	186713.728	231581.939
Government Budgetary Revenue[1] (Million RMB)	314948	348337	434895	521810	624220	740799	Central Government	422692	489200	584921	698917	858274
							Local Government	442422	498395	559487	640606	780330
Annual Growth Rate of Government Appropriation for Education Expenditure (Percentage) [1]	5.9	17.2	19.6	37.2	16.3	17.8	Central Government	12.0	27.1	7.9	1.5	22.0
							Local Government		13.8	17.2	16.7	24.0
Annual Growth Rate of Government Budgetary Revenue (Percentage)[1]	7.2	10.6	24.8	20.0	19.6	18.7	Central Government	16.8	15.7	19.6	19.5	22.8
							Local Government		12.7	12.3	14.5	21.8
Ratio of Appropriation of Central Governments to Local Government (Percentage)	N/A	N/A	N/A	N/A	N/A	N/A		13.1	14.6	13.5	11.7	11.5

Source: *China Statistics Yearbook 2002*; *China Education Yearbook 1998,1999,2000,2001,2002, 2003*; *China Statistical Yearbook on Science and Technology 2002*.
Note: 1. The data broken down at the local and central levels are not available for the period from 1991 to 1996.

3.3.2 Protection of Intellectual and Industrial Property

Since the 1990s the issue of protection of IPR has not only been an economic and juridical dilemma for China's central and local governments, but also a significant economic and political concern for a number of industry interest groups and governments of developed countries. The piracy problem in China has provoked much dispute between the Chinese government and its western counterparts, particularly between China and the US (Oksenberg et al., 1996).

The estimate of the piracy and infringement of IPR in China is only available in statistical report of the industry interest group such as International Intellectual Property Alliance and Business Software Alliance. Because of the lack of the third party's supporting statistics, the estimated figures issued in their annual reports (Table 3.10) should be assessed carefully. According to Business Software Alliance (2003), China's piracy rate showed modest improvement since 1994. Nevertheless, China had still the second highest piracy rate, i.e. 92 percent, in the world after Vietnam. The violation of IPR in China caused losses of 2.4 billion US Dollars in 2002, representing 44 percent of the total dollar losses in the Asia/Pacific region and 18 percent of the total world dollar losses.

In terms of patenting in European Patent Office (EPO), the US Patent and Trademark Office (USPTO) and the Japanese Patent Office (JPO) ("Triadic" patent families) (Table 3.7), China's application is scanty. This could be explained by the weak R&D activities in China, but we argue it is also caused by the unfavorable social culture toward IPR protection and the insufficient policy incentive. It is believed that as more Chinese domestic enterprises realize the value of IPR in the fierce competition of global market, the patenting in China will improve in the near future.

In their in-depth analysis of China's IPR protection issue from the perspective of politics and law, Oksenberg et al. (1996) examine the cultural and historical tradition of the IPR protection in China. They blame the Confucian tradition and the policy of the government in most of the time of the 20^{th} century, particularly in the Mao Era (1949-1976) for China's unsatisfying performance. They believe the traditional thoughts and current complex political-economic interrelationships in the central and local administration have great influence on the social norms that are unfavorable for IPR protection.

Table 3.10: Estimated Trade Losses (Million US Dollars) Due to Piracy and Piracy Rate (Percentage) in China: 1999-2003

Industry	1999		2000		2001		2002		2003	
	Loss	Piracy Rate	Loss	Piracy Rate	Loss	Piracy Rate	Loss	Piracy Rate	Loss	Piracy Rate
Motion Pictures	120.0	90	120.0	90	160.0	88	168.0	91	178.0	95
Records and Music	70.0	90	70.0	93	47.02	90	48.0	90	286.0	90
Business Software Applications[1]	437.2	91	765.1	94	1140.2	92	1637.3	92	N/A	N/A
Entertainment Software	1382.5	95	N/A	99	455.0	92	N/A	96	568.2	96
Books	128.0	N/A	130.0	N/A	130.0	N/A	40.0	N/A	40.0	N/A
Total	2137.7	-	1085.1	-	1932.5	-	1893.3	-	-	-

Source: International Intellectual Property Alliance (2004).
Note: 1. The trade loss of the Business Software Applications estimated in this table is different from the trade loss released separately in the annual global piracy study of the Business Software Alliance. Detail information is found in the original table.

In the OECD countries, the growing number of granted patents and patent applications showed the increasing importance of IPR in the innovation system of the industrialized countries (OECD, 2003b). Recently the progress of current IPR policy practice in the European countries highlighted three main themes: encouraging SMEs to apply for and exploit IPR; promoting IPR in public research institutes; and dealing with special issues such as IPR in software and biotechnology and the ongoing reforms of broadening ownership of IPR within higher education institution (European Commission, 2001b, 2002d).

Bearing in mind that China aims to foster innovation activities in national R&D institutions and build up the technological competitiveness of domestic enterprises in the international market, developing IPR system and enforcing IPR protection are the unavoidable choices for China's policy makers. The industrialized countries should not ignore the progress that China has made in establishing an IPR regime in a relatively short time. Their cooperation with China instead of the mere denouncement will finally expedite the improvement process of the regime.

To summarize this chapter, we utilize policy practices in the OECD countries as a guideline to examine China's innovation policy in five categories: reform in the public S&T institutions, financial policy, business innovation support structure, human resource policy and legislative actions. Through the in-depth analysis, education and human resource policy and protection of intellectual property rights are identified as weak components of the Chinese innovation policy framework. The policy actions in these two areas should be prioritized in China’s future innovation policy making.

Chapter 4 Scientific Productivity Paradox: The Case of China's S&T system[8]

China's science and technology achieved rapid development in the past two decades. Shown in Table 4.1, over the period of 1991-2002, the ratio of Chinese "Science Citation Index (SCI)" papers to the world total increased from 1.07 percent to 4.18 percent.[9] The patent application of the S&T institutes doubled. The contract value of technology transfer projects in 2002, measured by 1990 constant price, was two and a half times of the figure in 1991. In a global context, the number of Chinese SCI papers soared at a two-digit speed from 1998 to 2002, far surpassing its counterparts in the world as seen in Table 4.2. In 1998, China ranked 9th in the world in terms of the number of SCI papers, but in 2002 its position ascended to 5th. Based on the exponential growth of the China's scientific publication in the period of 1993-2003, Leydesdorff and Zhou (2005) conclude that China's increasing contribution is making unprecedented impact on the world scientific system. In another study, they uncover that China has the second largest share of the nanotechnology publication in the world after the US (Zhou and Leydesdorff, 2005).

The increasing governmental budget appropriation and outlay have played an overwhelming role in the rise of China's S&T. Besides, the reform in China's S&T institutes, beginning in 1985, is also deemed to have been a decisive factor in the progress of the entire sector. In this chapter, the so-called "China's S&T institutes" include three groups of R&D organizations: the sub-institutes of the Chinese Academy of Science; the institutes affiliated with ministries and central governmental agencies; and the institutes affiliated with local governments. Taken together, these institutes amounted to 5793 in 1986, though they decreased to 4347 in 2002. According to the various issues of *China Statistical Yearbook on Science and Technology*, in 1995, the aforementioned institutes hired 1.01 million staff; however, in 2002 only 590 thousand employees remained on their payrolls.

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[8] This chapter is adapted from Huang, Can; Varum, Celeste; Gouveia, Borges, 2006. Scientific Productivity Paradox: The Case of China's S&T system. *Scientometrics*, 69, 2, 449-473.
[9] "Science Citation Index", "Science Citation Index Expanded", "Engineering Index" and "Index to Scientific & Technical Proceedings" are widely used academic publication index systems, which are developed by Thomson ISI, based in the US.

Table 4.1: Output Indicators for Chinese S&T System: 1991 – 2002

Year	Number of China's "Science Citation Index" (SCI) Papers[1]	Ratio of China's SCI Papers to World Total SCI Papers (Percentage)	Number of Patent Application of China's S&T Institutes[2]	Contract Value Registered in Technology Markets (Sellers are S&T Institutes) (Unit: 1000 RMB, 1990 Constant Price)[2]
1991	6 630	1.07	2 385	4 167 097
1992	6 224	0.92	2 541	6 078 776
1993	9 617	1.28	2 636	6 353 850
1994	10 411	1.32	2 540	5 629 851
1995	13 134	1.54	2 345	5 961 984
1996	14 459	1.62	2 835	5 942 453
1997	16 883	1.84	2 829	6 310 247
1998	19 838	2.13	2 872	8 141 753
1999	24 476	2.51	3 048	8 981 310
2000	30 499	3.15	4 122	9 028 356
2001	35 685	N/A	4 360	9 745 492
2002	40 800	4.18	5 373	10 094 857

Source: 1. Institute of Scientific and Technological Information in China (2000, 2001, 2002, 2003).
2. *Chinese Statistical Yearbook on Science and Technology 2003.*

Table 4.2: S&T Papers Included in "Science Citation Index Expanded", "Engineering Index" and "Index to Scientific & Technical Proceedings": China and Several Other Countries

Country	Rank of the Number of Total S&T Papers in the World in 2002	Ratio of the Country's S&T Papers to the Total in the World in 2002 (Percentage)	Annual Growth Rate of the Country's S&T Paper (Percentage)			
			1999/1998	2000/1999	2001/2000	2002/2001
UK	3	7.95	N.A.	N.A.	N.A.	-4.36
Germany	4	7.35	N.A.	N.A.	5.29	-4.41
China	5	5.37	31.95	7.56	29.89	19.94
France	6	5.13	N.A	N.A	4.63	-4.25
Italy	7	3.84	-2.21	-2.86	9.69	-1.55
Canada	8	3.62	4.07	-4.46	2.08	0.20
Russia	9	2.89	1.06	-1.60	-5.82	11.83

Source: Institute of Scientific and Technological Information in China (2000, 2001, 2002, 2003).

Table 4.3 shows the declining importance of S&T institutes vis-à-vis universities and enterprises in the period of 1987-2002. This dynamic change is the outcome of the government's policy that seeks to strengthen industrial R&D. The growth of the R&D capability in industry and academia, nevertheless, did not come as a sacrifice in the development of S&T institutes. Presented in Table 4.3, the growth of R&D input of the S&T institutes in the 1990s, measured by R&D personnel and expenditure, is evident. Likewise, estimated by patent application and scientific papers, the S&T institutes' output increased in the same period as well.

4.1 The Two Decades Reform of S&T System in China

Gu (1999) explicitly describes the China's S&T system in the planned era as a linear innovation model (Figure 4.1).[10] In this system, governments at various levels exerted strong influence on R&D and innovation activities, fully controlled S&T funding allocation for basic and applied research and rigidly regulated experiment and development carried out in enterprises. Knowledge flow passed, unvaryingly, from basic research institute, namely Chinese Academy of Science to applied research institutes which were affiliated to ministries or local governments, then towards enterprises. Applied research institutes rarely transmitted their feedbacks back to the knowledge generator, i.e. basic research institutes. Similarly, the interactions between applied research institutes and enterprises were also feeble.

The linear innovation model not only dominated in China's S&T system, but also prevailed in the former socialist countries in Central and East Europe. In the studies of OECD (1969), Hanson and Pavitt (1987), Meske (1998) and Radosevic (2003), the scholars summarize the features of the planned S&T system such as that enterprises are not the center of innovation and R&D funding is distributed on the basis of institution's personnel scale (see the left column in Table 4.4). In contrast to the system based on market economy (right column in Table 4.4), the planned S&T system failed to efficiently make use of the human and physical resources to promote innovation. Accordingly, it lost the competition with the market economy system in terms of generating technological breakthrough to enhance citizen's welfare.

[10] See also various issues of the *Science and Technology White Papers* issued by State Science and Technology Committee of China (1986, 1987, 1988, 1989, 1993, 1997).

Table 4.3: S&T Institutes in China's Innovation System: 1987-2002

	Year	S&T Institutes	Ratio of value of S&T Institutes to the Sum (Percentage)	Universities	Ratio of the value of Universities to the Sum (Percentage)	Enterprises	Ratio of the value of Enterprises to the Sum (Percentage)
R&D Personnel (Thousand Person Year, Full Time Equivalent)	1987[1]	385.86	47.23	178.29	21.82	252.78	30.94
	1995	345.00	44.86	144.00	18.73	280.00	36.41
	2002	206.00	25.40	181.00	22.32	424.00	52.28
R&D Expenditure (Billion RMB, Current Price)	1987[2]	10.68	60.72	0.70	3.98	6.21	35.30
	1995	14.64	44.30	4.23	12.80	14.17[4]	42.89
	2002	35.13	33.71	13.05	12.52	56.02[4]	53.76
Number of Invention Patent Application in State Intellectual Property Office of P.R. China	1987[3]	1 844	29.35	1 360	21.65	3 078	49.00
	1995	865	34.26	574	22.73	1 086	43.01
	2002	3 429	15.33	4 282	19.14	14 657	65.53
Number of "Science Citation Index" Papers [5]	1999	3 927	29.84	9 214	70.03	17	0.13
	2002	8 036	25.80	23 028	73.94	82	0.26

Source: The data of 1995 and 2002 are from *China Statistical Yearbook on Science and Technology 2003*.
Note: 1. The data of 1987 are from Xue (1997). The data are the head count data.
2. The data of 1987 are from Xue (1997).
3. The data of 1987 are from Shen (1997). The data not only include the invention patent application, but also the utility model and the design patent application. Therefore, their values are larger than those of the year 1995 in the table.
4. The data are specified in *China Statistical Yearbook on Science and Technology 2003* as "R&D Expenditure". Their values are supposed to be larger than those of "Intramural R&D Expenditure" data.
5. The data are from Institute of Scientific and Technological Information in China (2000, 2001, 2002, and 2003). The data of 2002 are for "Science Citation Index Expended" papers. The data of 1999 are for "Science Citation Index" papers.

Figure 4.1: Chinese S&T System in the Planned Economy

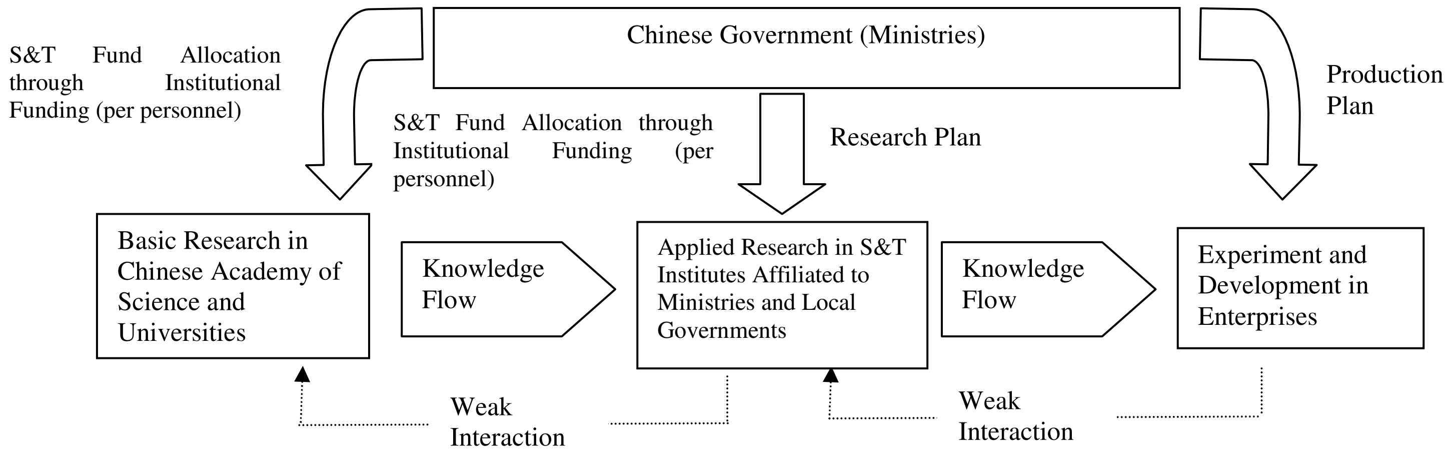


Figure 4.2: Chinese S&T System in the Market Economy

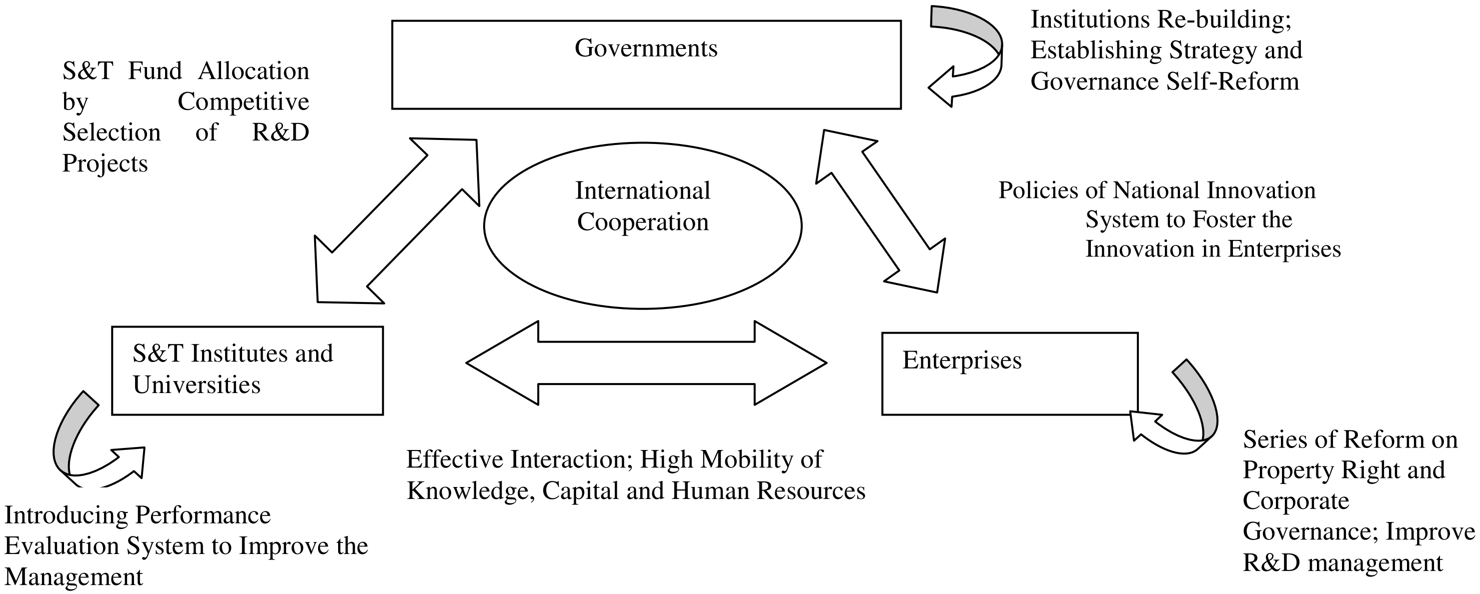


Table 4.4: Centrally Planned S&T System and Market-Oriented S&T System

S&T System in Centrally Planned Economy	S&T System in Market Economy
• Strong influence from political hierarchy and control; • Linear innovation model: o Innovation process is vertically segmented as basic research, applied research and experiment and development; o Innovation system is horizontally segmented by ministerial R&D branches; o Innovation push comes from externalized R&D towards production; o Users are not the source of improvement and innovation;	• Dynamic and interactive innovation system; o High mobility of the human resources, knowledge, capital inside innovation system; o Demand for innovation comes from not only "push side" such as R&D institutes, but also "pull side" such as users and enterprises;
• Enterprises are only production units instead of being the center of innovation; o R&D is "outsourced" to ministries or other organizations rather than being organized as an "in-house" activity; o Knowledge is accumulated more in design and engineering institutes than in enterprises; o Links between R&D and production are generally weak;	• Industrial R&D is driving force of innovation activities; o Technology is firm-specific assets; o Enterprises accumulate embodied knowledge through learning-by-doing in the specific organizational contexts; o Enterprises create pull-demand for innovation;
• R&D funding is distributed on the basis of institution's personnel scale, instead of depending on merit of the projects;	• R&D project funding is determined by the competition between proposals, i.e. based on the merit of project;
• "Soft Budget Constraint" prevails inside the R&D units; o Low efficiency of R&D activities; o Overstaffing is a serious problem.	• "Hard Budget Constraint" guarantees efficiency in daily operation and management of R&D units.

Source: Hanson and Pavitt (1987), Meske (1998), OECD (1969) and Radosevic (1999).

The superior S&T performance which was achieved in the west industrialized countries, made the governments in China and the CEECs gradually recognize the institutional constraint of the planned S&T system. Some remedy initiatives were subsequently designed and launched in the late 20th century. The reform in China was put on agenda in the middle of the 1980s. The objective of the reform was not clearly defined by policy makers at the very outset, however, revealed by the trajectory of the system's evolution over the past twenty years, the series of policies did progressively transform the rigid, segmented and inefficient plan-oriented S&T system towards a highly dynamic, interactive and efficient system, such as those in the leading industrialized countries. Through the reform, the effective and efficient interaction among governments, S&T institutes, universities and enterprises needs to be established. Competitive S&T funding system, well-functioned national innovation policy and effective R&D management system inside S&T institutes and enterprises ought to be in place (see above Figure 4.2).

In the past 20 years, various policies regarding S&T system transformation have been implemented in China. To distinguish the vital initiatives from their follow-up measures with less importance, we classify the policies along three lines, which are 1) reforming the R&D funding system, 2) improving R&D management in the S&T institutes and 3) strengthening the industry-academy relationships. This classification helps us grasp the far-reaching change of China's S&T system in the past two decades.

4.1.1 The reform of the S&T funding system

At the beginning of the reform, the Chinese government quickly realized that increasing the budget appropriations of S&T institutes would not solve the efficiency problem completely. The centrally planned funding mechanism based on scale of institutes or number of staff would squander much of the resource invested towards the S&T sector. By recognizing it, shortly after issuing "the resolution" in 1985, the government transferred the responsibility of allocating S&T funding from the Ministry of Treasure to the State Science and Technology Commission, which later turned into Ministry of Science and Technology. In the following years, while China's government steadily increased the S&T budgetary appropriation, a series of programs such as the 863 Program, 973 Program and Key Technology R&D Program (*Gong Guan* Program) were developed to manage the R&D projects under the leadership of Ministry of Science and Technology.[11] In addition, the National Natural Science Foundation of China (NSFC) was established to manage the funding to basic research, based on evaluating the merit of research proposals (Xue, 1997).[12]

The annual growth rates of the central government's appropriation to S&T activities were significantly higher in the 1990s than in the 1980s. Since the second half of the 1990s, the budgetary support had even rocketed at a two-digit speed (Table 4.5). The strengthened governmental R&D inputs contributed to the growth of China's ratio of Gross Expenditure on R&D/GDP in the recent years (Figure 4.3). The competitive funding system that allocates the public R&D grant in accordance with the merit of research proposals was one of the major achievements of China's two decade long S&T system reform. Its establishment evidenced the government's attempt to improve the scientific productivity, which has never been given emphasis in the planned era.

4.1.2 The improvement of the R&D management in the S&T institutes

Improving the management in the S&T institutes is another measure that China's government embraced in the effort to enhance scientific productivity. Between 1985 and 1987, the system of "working position title" such as "Professor, Associated Professor, Researcher, Associated Researcher, etc." was established. The position system coupled with the remuneration differentiation policy motivated the research staffs and encouraged the mobility of human resources. After the late 1980s, the directors of the S&T institutes were obliged to sign working contracts with the governments. At the same time, they were granted more autonomy for personnel, finance, property management and international cooperation.

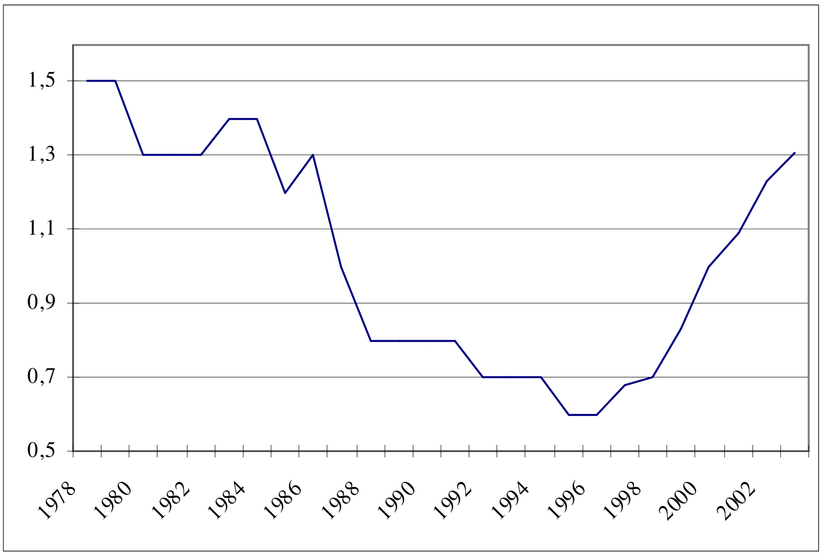
[11] The description of Chinese S&T programs can be read in Huang, et al. (2004). Currently, the 863 Program, 973 Program and Key Technology R&D Program (*Gong Guan* Program) consisted of three major funding programs managed by Ministry of Science and Technology. The budgets of these three programs reached 5.5, 0.9, 1.5 billion RMB in 2004, respectively. (The exchange rate of US Dollar to RMB was 1:8.27 at the end of 2004.)
[12] In 2004, the budget of NSFC amounted to 2.246 billion RMB. The number of the received research proposals by NSFC topped 42 984, increased by 21.8 percent from the figure in 2003 and were around four times of the figure in 1987 (NSFC, 2006; State Science and Technology Committee, 1988).

Table 4.5: Chinese Central Government's Budgetary Expenditure and Appropriation for S&T: 1980-2002[1]

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Budgetary Appropriation for S&T (Billion RMB. Constant Price. 1990=100)	10.91	10.17	10.80	12.94	14.78	14.54	15.25	14.67	13.93	13.51	13.91	15.06
The Annual Growth Rate of Budgetary of Appropriation for S&T (Percentage)		-6.8	6.2	19.8	14.3	-1.7	4.9	-3.8	-5.1	-3.0	3.0	8.2
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	
Budgetary Appropriation for S&T (Billion RMB. Constant Price. 1990=100)	16.43	17.10	16.96	16.89	18.39	21.39	23.51	29.80	31.25	37.73	44.04	
The Annual Growth Rate of Budgetary of Appropriation for S&T (Percentage)	9.2	4.1	-0.8	-0.4	8.9	16.3	9.9	26.8	4.8	20.8	16.7	

Source: *China Statistical Yearbook on Science and Technology 2003*.
Note: 1. The original data are current price data. The constant price transformation is based on the GDP deflator provided by the World Bank.

Figure 4.3: China's Gross Expenditure on R&D/GDP Ratio: 1978-2003



Source: Various issues of *China Statistical Yearbook on Science and Technology*.

The more ambitious reform known as the "Knowledge Innovation Program" was launched in 1998 in the Chinese Academy of Science. The program aimed to consolidate the Academy through reducing the 68000 permanent positions to 30000 by 2010 via retirements and re-assigning people to alternate positions. The remaining positions were given to the most productive staff (*Science*, 2001). While the emphasis was given to reducing redundant personnel, the efforts were also made to recruit the overseas Chinese scientists.[13] The large scale "brain drain" in China has decreased in recent years largely through active expatriate scientist recruitment programs (Cao, 2002). Since the 1990s, the R&D management in China's S&T institutes was gradually improved, by and large through learning from state-of-art management practice in advanced countries. In the case study on the reform of Shanghai Biotechnology Engineering Center (SBEC), Zhao (2003) describes the pre-reform R&D management in SBEC was better characterized as technology-push style, which lacked strategic framework and specific profit objective. Resource plan and thorough R&D performance evaluation were not emphasized by SBEC's managers, either. Through reform, SBEC aimed to improve the management by managing R&D on the basis of research project and measuring research outcome through financial indicators such as net present value, return of investment and payout ratio etc.

[13] According to the US National Science Foundation (2001), more than 21600 Chinese earned Science and Engineering (S&E) Doctorates at the US universities over the period of 1986-98, which is around 7.5 percent of all S&E Doctorates in the US universities.

4.1.3 Strengthening the academy and industry relationship

Strengthening the industry-academy relationship was prioritized in the “Resolution” of 1985 in China. The government designed the push- and pull-side policies to develop the linkages between industry and academia.

On the one hand, the “push-side” policy executed in the 1980s gradually reduced the government’s budgetary appropriation to the S&T institutes. This strategy succeeded to force institutes to turn towards enterprises to earn revenue. The technical service provided to enterprises and the joint R&D projects financed by industry became more important to S&T institutes because they brought in an increasing proportion of the total revenue of institutes. Xue (1997) reported that the ratio of government appropriation to the budget of S&T institutes decreased by 5 percent on average each year from 1986 to 1993. After 1985, S&T institutes, especially those doing experiment and development were encouraged to merge into enterprises. The newest round of reform after 1999 even went further to transform hundreds of S&T institutes into enterprises or non-profit organizations (Huang et al., 2004). Meanwhile, the government concentrated its funding on the unchanged institutes that primarily conduct basic research.

On the other hand, the “pull-side” policy focused on the establishment of the “technology market” which facilitated the technology transfer from academia to industry. The transfer was promoted by the “Technology Contract Law” taking effect on Nov. 1, 1987 and the subsequent relevant regulations. The registered contract value of the technology transfer projects achieved the remarkable growth during 1990s as seen in Table 4.1. In addition, the spin-off enterprise was also strongly promoted by the government. Gu (1999) reported that the first spin-off enterprise from Chinese S&T institutes was set up in 1980, but the strong promotion led by the governmental “Torch Program” only initiated in 1998. The program supported hundreds of Science Park and incubators across the country (Huang et al., 2004). Promoted by the government’s S&T policy, Chinese spin-off enterprises showed the dynamism in their access to new technology, efficient corporate governance, aggressive business strategy and strong learning capability (Lu, 2001).[14]

4.2 Scientific Productivity of Chinese S&T Institutes during the Reform[15]

As discussed above, various initiatives have been put into effect to improve the efficiency or productivity of China's S&T sector. However, few in-depth studies have been made to evaluate the reform policy performance. One exception is Liu and White (2001)'s study that analyzes social and economic factors' contribution to China's regional patenting activity over the period of 1985-1995, but their estimation of R&D input-output causal relationship was weakened by the ad-hoc treatment of the lag structure of input and output. In this chapter, we fill the vacancy of the literature through introducing a lag distribution model to measure the scientific productivity of China's S&T institutes.

4.2.1 Methodology

Following Adams and Griliches (1996a, 1996b), we adopt a scientific production function (function (1), log-linear form) to estimate the scientific productivity.

(1)
$$y = \alpha + \beta W(r) + \gamma X + u$$

where *y* is logarithm of the research output which can be measured by paper, citation or patent, *W(r)* is the logarithm of a distributed lag function of the past R&D expenditure, representing the stock of R&D investment, *X* is a set of control variables, normally including a time trend variable *t* to control the changes of the variables over time, whereas *u* represents all the other unaccounted factors contributing to the output. The key issue of this function is the specific form of the *W(r)* and its estimation.

[14] Some spin-off companies have grown up to compete in the international market, such as the PC company Lenovo. It spun off from the Institute of Computing Technology, Chinese Academy of Science in 1984 and in 2004 acquired the IBM personal computing division to create the world's third largest PC business with approximately 12 billion US Dollars annual revenue in 2003 (Lenovo, 2004).
[15] The econometric results in the chapter are obtained through the software of Eviews 4.1.

Crespi and Geuna (2004) utilized the polynomial distributed lag (PDL) model as the form of *W(r)* to analyze the data of the 14 OECD countries in the period of 1981-2002.[16] The proper lag structure can be searched through various information criteria in the PDL model. Thus, the method is able to trace the full impact of past R&D input on output, which can not be found completely through the ad hoc lag structure proposed by Adams and Griliches (1996b) and Liu and White (2001). Following Crespi and Geuna (2004), we base our analysis on the following polynomial distributed lag model (Quantitative Micro Software, 2002) as

(2) $$y_t = \alpha + \sum_{j=0}^{k} \beta_j r_{t-j} + \lambda t + u_t$$

(3) $$\beta_j = \delta_0 + \delta_1 (j-c) + \delta_2 (j-c)^2 + ... + \delta_p (j-c)^p \, (j = 0,1,...k > p)$$

where c is a pre-specified constant given by

(4) $$c = \begin{cases} (k)/2 & \text{if p is even} \\ (k-1)/2 & \text{if p is odd} \end{cases}$$

When running the regression, the function (2) is substituted by

(5) $$y_t = \alpha + \delta_0 z_0 + \delta_1 z_1 + ... + \delta_p z_p + \lambda t + u_t$$

where

(6) $$\begin{aligned} z_0 &= r_t + r_{t-1} + ... + r_{t-j} \\ z_1 &= -c r_t + (1-c) r_{t-1} + ... + (j-c) r_{t-j} \\ &\cdots \\ z_{p+1} &= (-c)^p r_t + (1-c)^p r_{t-1} + ... + (j-c)^p r_{t-j} \end{aligned}$$

[16] A strand of literature following Hausman, et al. (1984) develops the count data (nonnegative integers) models to analyze the relationship between patents and R&D expenditure. The count data models have advantages when the dependent variable data (the counts of number) are zero or small. When the count of number is large, the model based on continuous approximation is able to render unbiased estimation. All our data are large counts of number. Therefore, we do not implement count data models in this section.

Once the δ is estimated from the function (5), β can be recovered straightforward through function (3) since β is a linear transformation of δ. The constant c is included only to avoid numerical problems that arise from colinearity and does not affect the estimates of β. The minimal value of Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC) indicates the appropriate lag length j of the model (Brockwell and Davis, 1991, p. 301; Crespi and Geuna, 2004). The definitions of the AIC and SIC are given in the following equations

(7) $$\text{AIC} = -2(l/n) + 2(s/n)$$

(8) $$\text{SIC} = -2(l/n) + s\log(n)/n$$

where l is the value of the log of the likelihood function with the s parameters estimated using observations n (Quantitative Micro Software, 2002). Based on the equation (5), here $s = p+3$. Knowing that the full effect of R&D expenditure in the higher education sectors of the 14 OECD countries takes 6 years to occur, i.e. j=6 (Crespi and Geuna, 2004), we start to search the lag length from a lag of 6 years in our analysis on China. We look for the right polynomial degree p by testing sequential unit reduction of its value from the initial value of 5.

After the βs are obtained from the estimation of the function (2), we proceed to calculate the growth of scientific productivity between the period t and $t\text{-}1$ according to the following equation

(9) $$\text{Scientific Productivity Growth} = (y_t - y_{t-1}) - \sum_{j=0}^{k} \hat{\beta}_j (r_{t-j} - r_{t-1-j})$$

where $\hat{\beta}_j$ is the estimated coefficient of the function (2).

When reporting the growth of scientific productivity, we may present the annual scientific productivity growth rate. The growth rate from time t to time $t+1$ is commonly taken to be (Scientific Productivity $_{t+1}$ – Scientific Productivity $_t$)/ Scientific Productivity $_t$. Since $ln(1+r)$ is approximately equal to r for small r, the scientific productivity growth rate can be approximated by the difference in logarithms, i.e. *ln*

Scientific Productivity $_{t+1}$ – *ln* Scientific Productivity $_t$. Therefore, the average annual scientific productivity growth rate between the period *s* and *t* is obtained by (*ln* Scientific Productivity $_t$ – *ln* Scientific Productivity $_s$)/(*t*-*s*).

4.2.2 Data

The data of Chinese S&T institutes are from two sources: 1) *China Statistical Yearbook on Science and Technology* (*Zhong Guo Ke Ji Tong Ji Nian Jian,* hereafter it is called "Yearbook") and 2) *Data Set of S&T Organizations* (*Ke Ji Ji Gou Tong Ji Shu Ju Ji*, hereafter called "Dataset"). The first *China Statistical Yearbook on Science and Technology* was published in 1991, covering the data of 1990. The *Data Set of S&T Organizations* was firstly issued in 1986, publishing the annual statistic data of China's S&T institutes.

The Chinese S&T statistics system was established less than 20 years ago. For this reason, the early S&T data were more problematic than the recent ones, which poses difficulty to our time series analysis. Moreover, the early versions of the data sources merely included fewer statistical indicators. For instance, the usual R&D input indicator such as R&D intramural expenditure was not reported in the early period. Therefore, we have to adopt the more consistent "expenditures of R&D projects", instead of "R&D intramural expenditure" as the R&D input data in the analysis. The R&D output is measured here by "the count of papers published in the international journals, books and conference proceedings" (*Ke Ji Lun Wen, Guo Wai Fa Biao*, hereafter called "international paper") and "the count of the patent applications in Chinese patent office" (hereafter called "patent application").

In addition to international publication, the dataset also report "all the domestic and international publication". The reason that we only consider the papers published abroad in this analysis is derived from the previous research on the pattern of Chinese scientific publication. Moed (2002) finds that relative to the world average impact of all articles indexed by ISI, the impact of the publications in the journals which mainly publish Chinese language articles and in the journals publishing the articles whose authors are mainly from China is very low. Ren and Rousseau (2002) argue that the papers written by Chinese scientists, but published in Chinese journals should not be classified as international articles due to their low international visibility. They point out the international impact of Chinese journals is relatively limited as well. The findings in these two studies are echoed by some research focusing on the specific scientific field, such as laser research (Garg, 2002) and computer science (Guan and Ma, 2004; Kumar and Garg, 2005). For the reason that Chinese scientists' domestic publication might suffer from low quality and international visibility, we measure scientific publication of Chinese S&T institutes merely through the articles published abroad.

To estimate the function (2), the R&D project expenditure and patent application data are taken from the "yearbook". The international papers data are from "dataset". All of data series cover the period of 1986-2003. These data are aggregate data at the country level, collected from all the S&T institutes in China. Utilizing the coefficients of βs obtained from the estimation result of the function (2), we can calculate the aggregate scientific productivity of China's S&T institutes through the equation (9). All the expenditure series are converted by China's GDP deflator into 1990 constant price. Figure 4.4 displays the aggregate data from the "Yearbook" for estimating the function (2). All three data series show the evident upward trend.

In order to test the robustness of the aggregate scientific productivity, we take advantage of the provincial level data in the "dataset" to calculate the scientific productivity of the S&T institutes in some provinces. The comparison of the aggregate data result and the provincial data result would reach a robust conclusion of the scientific productivity of China's S&T institutes in the past decades. The provincial R&D project expenditure data and publication data in the "dataset" cover the period of 1991-1995 and 1997-2003. The provincial patent data solely cover the period of 1992-1995 and 1997-2003. This means all 1996 data in the "dataset" are missing. Taking account of the fact that these three data series are rather smooth, namely, without much variation between two neighboring years, we fill the vacancy of the 1996 data with the average of 1995 and 1997 data.

Table 4.6 provides some general information of the provincial level data from the "dataset". It demonstrates that eleven out of thirty one provinces in China (hereafter called "top eleven" provinces), spent around 80 percent of national R&D project expenditures in 1991 and 2003. About 80 percent of China's international paper publications and patent application were also concentrated in these eleven provinces. These mean that the "top eleven" provinces absorbed the majority of R&D resources in China and produced a significant proportion of R&D output in the country. Furthermore, the ranks of these provinces varied little between 1991 and 2003. To achieve simplification, we only report the scientific productivity of these eleven provinces, instead of presenting a result embracing 31 provinces.

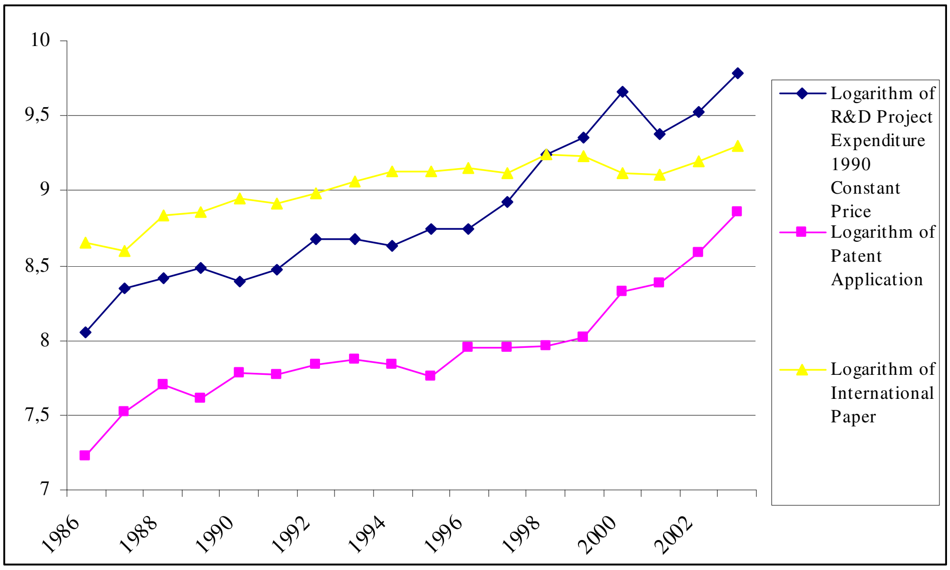
4.2.3 Unit Root Test

Before running the function (2), we test whether the data series are with unit roots or with deterministic time trends. If the test rejects the hypothesis of unit root, it would justify our including a time trend variable t into the function (2), otherwise, we have to run the regression based on the difference of the neighboring period data.[17] However, the limited number of the available observations makes it impossible to obtain accurate result by means of some unit root test methods, including Augmented Dickey-Fuller (1979), Phillips-Perron (1998) and GLS-detrended Dickey-Fuller (Elliot et al., 1996). Fortunately the method of KPSS (Kwiatkowski et al., 1992) was not affected by this difficulty. Based on the result of KPSS method (Table 4.7), the judgment whether the data series are with unit roots depends on the level of significance we choose. This means we can not safely reject or accept the null hypothesis on the basis of the limited observations.

Because of the ambiguity in the econometric result, we would like to examine this issue from the realistic perspective. The reality is that the Chinese government did attempt to increase R&D funding and improve the performance of the S&T sector in the past years. As a consequence, the R&D data series having an obvious stable upward trend would be better analyzed with the deterministic time trends, rather than with the unit roots. The similar inference that the country's aggregate R&D input and output data series are with the deterministic time trends are also made by Crespi and Geuna (2004) based on the data of the OECD countries. They rejected the unit root hypothesis in their test based on the 14 OECD countries' R&D input and output data. All in all, we do not calculate the difference of the neighboring period data to run the function (2).

[17] More elaborate discussion of this issue can be found in Hamilton (1994, p.486).

Figure 4.4: R&D Input and Output in Chinese S&T Institutes: Aggregate Data



Source: Various issues of *China Statistical Yearbook on Science and Technology*.

Table 4.6: R&D Input and Output of China's S&T Institutes at Provincial Level

Province	Share of Specific Province's R&D Project Expenditure in the Country's Total R&D Project Expenditure				Share of Specific Province's International Papers in the Country's Total International Papers		Share of Specific Province's Patent Applications in the Country's Total Patent Applications	
	1991		2003		1991	2003	1992	2003
	Percentage	Rank	Percentage	Rank	Percentage			
Bei Jing	31.7	1	41.8	1	42.0	47.8	23.7	29.8
Liao Ning	5.5	3	4.9	3	7.6	5.4	9.4	10.1
Ji Lin	5.4	5	4.4	5	4.9	4.0	4.1	7.1
Shang Hai	12.3	2	10.6	2	12.1	13.4	7.5	17.1
Jiang Su	4.4	6	3.7	6	3.5	4.0	4.2	2.6
Shan Dong	2.3	11	3.0	9	1.6	1.6	6.3	3.5
Hu Bei	2.8	10	3.4	8	2.0	2.3	3.2	2.3
Guang Dong	3.1	8	4.4	4	4.9	3.0	2.7	4.5
Si Chuan	5.5	4	3.5	7	1.9	0.8	4.7	2.4
Shaan Xi	3.0	9	1.5	14	1.5	0.8	2.4	1.5
Gan Su	3.1	7	2.5	10	3.6	2.3	2.4	2.9
Share of Sum of Above "Top Eleven" Provinces' Data in the Country's Total (Percentage)	79.0	-	83.4	-	85.5	85.4	70.8	83.8

Source: *Data Set of S&T Organizations*.

Table 4.7: Unit Root Test of the Aggregate Data Series: Kwiatkowski-Phillips-Schmidt-Shin Method[1]

Null Hypothesis: The Data Series are Stationary	Kwiatkowski-Phillips-Schmidt-Shin Test Statistic	Asymptotic Critical Values		
		1% level	5% level	10% level
Logarithm of R&D Project Expenditure 1990 Constant Price	0.129737	0.216	0.146	0.119
Logarithm of International Paper	0.161040			
Logarithm of Patent Application	0.133574			

Note: 1. The exogenous variables in the regression include the constant term and linear trend.

4.2.4 Estimation Results

In the estimation result of function (2) (Table 4.8), by examining the AIC and SIC values we choose the 7 lags and 5 lags as the optimal lag structures for the publication and the patent data, respectively. The proper polynomial degree of the model for publication is 3rd because the F-statistic value turned to be significant when the degree is reduced from 3rd to 2nd. Likewise, the right degree of the model for patent is determined to be 1st. This proper function form reveals that in China's S&T institutes the full effect of the R&D investment on the international publication takes 7 years to occur and its total effect on patent application lasts 5 years.

The sum of lags, i.e. the sum of the elasticity of the output and the each period input, represents the long term elasticity of the R&D output and input. Our result shows the long term elasticity of publishing international papers and R&D project expenditure in China's S&T institutes is around 0.8 and the elasticity of patent application and R&D investment is approximately 2. That is, a 1 percent increase of the R&D investment in China's S&T institutes leads to 0.8 percent growth of the international papers and 2 percent growth of the patent application.

Table 4.8: Estimation Result of Function: International Paper and Patent Application

Independent Variable	Coefficients (Standard Deviation)					
	International Paper			Patent Application		
	8 Lags	7 Lags	6 Lags	6 Lags	5 Lags	4 lags
Expenditure $t_0(\beta_0)$	0.059 (0.085)	0.042 (0.066)	-0.029 (0.082)	0.262 (0.094)**	0.201 (0.061)***	0.190 (0.096)**
t_{-1} (β_{-1})	-0.116 (0.054)**	-0.100 (0.040)**	-0.101 (0.054)*	0.287 (0.071)***	0.252 (0.044)***	0.257 (0.064)***
t_{-2} (β_{-2})	-0.133 (0.049)**	-0.113 (0.040)**	-0.115 (0.052)**	0.312 (0.056)***	0.303 (0.033)***	0.324 (0.048)***
t_{-3} (β_{-3})	-0.050 (0.041)	-0.037 (0.031)	-0.074 (0.037)**	0.337 (0.055)***	0.354 (0.033)***	0.391 (0.060)***
t_{-4} (β_{-4})	0.075 (0.047)	0.089 (0.036)**	0.022 (0.046)	0.362 (0.068)***	0.405 (0.044)***	0.458 (0.089)***
t_{-5} (β_{-5})	0.185 (0.069)**	0.226 (0.054)***	0.168 (0.062)**	0.387 (0.090)***	0.456 (0.060)***	
t_{-6} (β_{-6})	0.221 (0.093)**	0.335 (0.079)***	0.363 (0.145)**	0.413 (0.116)***		
t_{-7} (β_{-7})	0.125 (0.117)	0.377 (0.135)**				
t_{-8} (β_{-8})	-0.159 (0.166)					
Sum of Lags	0.206 (0.513)	0.817 (0.324)**	0.234 (0.270)	2.360 (0.382)***	1.971 (0.186)***	1.620 (0.240)***
Constant	7.309 (3.956)	2.556 (2.512)	7.055 (2.091)***	-11.167 (2.951)***	-8.125 (1.441)***	-5.368 (1.868)***
Time Trend Variable t	0.010 (0.039)	-0.026 (0.024)	0.016 (0.022)	-0.118 (0.034)***	-0.093 (0.018)***	-0.072 (0.023)***
AIC	-3.474	-3.719	-3.194	-2.064	-2.968	-2.100
SIC	-3.293	-3.502	-2.951	-1.902	-2.794	-1.918
Polynomial Degree Reduction Wald Coefficient Test (P value of F-statistics)						
5 to 4		0.996				
4 to 3		0.567*				
3 to 2					0.649	
2 to 1					0.580	
1 to 0					0.036**	

Note: * denotes significant at 0.1; ** denotes significant at 0.05; *** denotes significant at 0.01.

With the βs obtained from the function (2), we calculate the aggregate scientific productivity growth rate through the equation (9) (Table 4.9). By measuring the output as patent application, we can trace the scientific productivity growth rate of China's S&T institutes until the early period of 1991/1992. But when output is measured by publication, we only can find the scientific productivity as early as in the period of 1993/1994. This dissimilarity of earliest periods is due to the two types of data's different lag structures. The average annual scientific productivity growth rate in terms of publication is -2.9 percent and in terms of patent it is -9.5 percent.

The finding of the negative scientific productivity growth rate of China's S&T institutions in the 1990s from the aggregate data is confirmed by the provincial data result in Table 4.10. The weighted averages of the scientific productivity growth rates of the "top eleven" provinces are negative, whenever the output is measured by the publication or patent data. It is noteworthy that the reporting period of the provincial publication data result is 1998-2003 and that of patent data result is 1996-2003. They are different from reporting periods of the aggregate data results in Table 4.9. In order to form a comparable outcome, we modify the reporting periods of the aggregate data results to present the scientific productivity growth of aggregate publication data in the period of 1998-2003 and that of aggregate patent data in the period of 1996-2003 in Table 4.10. The "top eleven" provinces' performance in terms of international publication was worse then the national average level in the period of 1998-2003, but if we measure the scientific productivity by patent application, the S&T institutes in these provinces outperformed those in the other regions in the period of 1996-2003. Presented in Table 4.10, the exceptional performance was achieved by the S&T institutes in Shang Hai (ranked 2nd among the 31 provinces in 2003 in terms of R&D input scale) and Gan Su (ranked 10th). The scientific productivity of the S&T institutes in these two provinces, measured by the publication or patent data, did achieve a continuous improvement. This finding is worthy of further research, which could point out a possible direction of future reform actions.

Table 4.9: Scientific Productivity Growth Rate of China's S&T Institutes: Aggregate Data

	Scientific Productivity Growth Rate in Terms of International Paper (Percentage)	Scientific Productivity Growth Rate in Terms of Patent Application (Percentage)
1991/1992	N.A.	-15.3
1992/1993	N.A.	-6.6
1993/1994	-4.8	-11.2
1994/1995	-3.5	-15.7
1995/1996	-0.2	5.9
1996/1997	-7.3	-15.0
1997/1998	4.4	-11.9
1998/1999	-3.9	-11.8
1999/2000	-8.2	0.0
2000/2001	1.5	-18.4
2001/2002	-1.6	-9.5
2002/2003	-5.5	-4.2
	Average Annual Growth Rate (Percentage)	
1991/2003		-9.5
1993/2003	-2.9	

Table 4.10: Average Annual Scientific Productivity Growth Rate of the S&T Institutes in the "Top Eleven" Provinces

Province	Average Annual Scientific Productivity Growth Rate in Terms of International Paper (Percentage)	Average Annual Scientific Productivity Growth Rate in Terms of Patent Application (Percentage)
	1998-2003	1996-2003
Bei Jing	-5.0	-7.1
Liao Ning	-2.8	-4.2
Ji Lin	0.9	-2.1
Shang Hai	2.3	3.6
Jiang Su	-9.4	-18.5
Shan Dong	-7.4	-23.0
Hu Bei	-11.7	-7.2
Guang Dong	-9.6	-6.6
Si Chuan	-12.4	1.3
Shaan Xi	-16.1	-5.8
Gan Su	0.2	1.4
Weighted Arithmetic Average[1]	-4.8	-5.7
Result of Aggregate Data (Percentage)		
1998/2003	-3.5	
1996/2003		-10.1

Note: 1. The weight is the ratio of the "R&D Projects Expenditure" of the specific province to the sum of the "R&D Projects Expenditure" of the "top eleven" provinces'.

To summarize, this chapter examines the transformation of China's Science & Technology sector inherited from the planned economy. To disclose the impact of the lasting reform on the efficiency of the whole sector, we measure the scientific productivity of China's S&T institutes. The R&D input and output data analysis is implemented at country aggregate and provincial level. Polynomial Distributed Lag model is used to uncover the structure of the lag between R&D input and output. The findings reveal that the growth rate of scientific productivity of China's S&T institutes has been negative since the 1990s. Accordingly, the policy actions are called for to address and invert the declining trend of the scientific productivity of the Chinese S&T institutes.

Chapter 5 Why the Manufacturing Firms in Developing Countries can be Competitive? The Evidence of China[18]

A commonly discussed topic in trade literature has been the export performance of countries, industries, and firms (Glejser et al., 1980; Daniels, 1993; Gustavsson et al., 1999; Carlin et al., 2001). A majority of the studies in this area examine cases of exportation in industrialized countries. Only a handful of studies such as those by Aggarwal (2002) on Indian firms, Zhao and Li (1997) and Liu and Shu (2003) on Chinese industry, and Ozcelik and Taymaz (2004) on Turkish firms have focused on the export industry in developing countries. One of the reasons that so little research has been done on developing countries is the dearth of sound data. A more plausible explanation, we argue, is the lack of technological competitiveness, which has made it difficult for firms in the developing world to export a broad range of manufactured products until recently.

The 1970's was the watershed in the trade structure transformation of developing countries. Before then, their major export merchandise was limited to raw materials such as petroleum and coal and labor-intensive products such as textile and footwear products (Krugman and Obstfeld, 2000, p.79). Between 1960 and 2001, the export share in the world trade of manufactured goods in developing countries gradually increased from 12 percent to 65 percent. During the same period, their share of primary commodities, excluding fuels, fell from 63 percent to 13 percent (UNCTAD, 2005). The main contributors of these trends were the Southeast Asian countries. Manufacturing exports from China, for example, grew twice as fast as the world average after the mid-1990's. These exports included eight products—leather and furs, footwear, cement and ceramics, base metals, machinery and electronic products, transportation equipment, optical and precision instruments, and miscellaneous manufactured products—which grew much more rapidly than those of the other sectors between 1985 and 2003 (see

[18] This chapter is adapted from the unpublished manuscript, Huang, Can; Zhang, Mingqian; Zhao, Yanyun; Varum, Celeste, 2006. Why the Manufacturing Firms in Developing Countries can be Competitive? The Evidence of China. The manuscript was presented in The 5th China Economics Annual Conference, Xia Men, P.R. China, December 10-11, 2005.

Table 5.1). China's export volume was 16.8 times as high in 1985 as it was in 2003. However, the export growth of certain product categories was even more outstanding: exports of machinery, electrical equipment, and electronic products were 497 times as high, and the volume of optical products and precision instrument products 215 times. These numbers reflect a major shift in China's export competitiveness from labor- and natural resource-intensive sectors to capital-intensive sectors such as transportation equipment and high-technology (high-tech) sectors such as electronic, optical, and precision instrument manufacturing. [19]

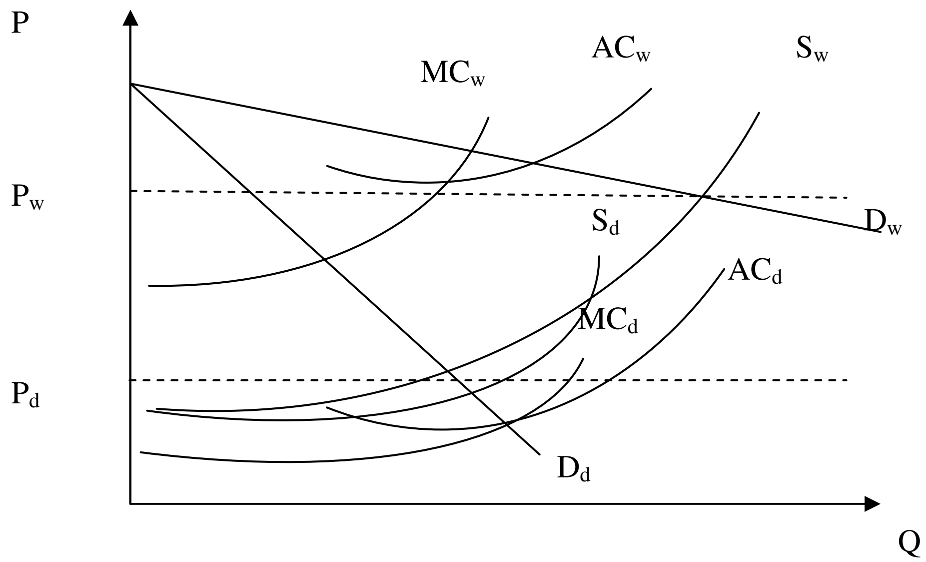
5.1 The Characteristics and Export Performance of Chinese Manufacturing Firms

We sketch the relationship between the characteristics of Chinese manufacturing firms and their export performance from a theoretical point of view. We assume that the domestic and international markets that a typical Chinese manufacturing firm might enter are, to some degree, segmented. Segmentation could be the result of differences between transportation costs, standards, and consumer taste in domestic markets and those in foreign markets. Segmentation would also be the result of export tariffs and the non-perfect-substitution between the products in domestic and foreign markets.

In our analysis (Figure 5.1), the typical Chinese firm is a price-taker in both domestic and international markets and intends to export. D_w and D_d denote international and domestic market demand, respectively, while international market demand is more elastic with respect to price than domestic market demand. International market supply S_w and demand D_w determine the price in international market P_w. Similarly, P_d, the price in the domestic market, is lower than P_w. A firm earns profits in the domestic market since the domestic price is higher than its average production cost for domestic market AC_d. However, it does not earn profits in the international market because its average production cost AC_w is higher than the international market price. To enter the international market, a firm has to push AC_w down to AC_w'.

[19] In this paper, we adopt OECD's classification of low-, medium-, and high-technology sectors (OECD, 2003, p.156). Manufacturing industries are classified by OECD in four different categories of technological intensity: high technology, medium-high technology, medium-low technology, and low technology. The classification is based on indicators of (direct as well as indirect) technological intensity, which include R&D expenditures divided by value added, R&D expenditures divided by production, and R&D expenditures plus technology embodied in intermediate and capital goods divided by production.

Figure 5.1: Firm's Export Price and Production Cost



One action that the firm could take to lower production costs is to lower labor costs. Particularly in the context of Chinese exporting industries, low labor costs have been considered the primary advantage of Chinese firms in the international market. Although Lall and Albaladejo (2004) and Shafaeddin (2004) argued that China's admission to the World Trade Organization (WTO) would not endanger the global market share of certain labor-intensive products of other developing nations, a major concern about China's integration into the world trade market was whether its products would dominate in sectors in which the low-cost advantage of "made in China" products was overwhelming. To measure the impact of labor costs on the export performance of Chinese manufacturing firms, we include the variable of unit labor cost in the econometric function below.

Table 5.1: China's Export Structure Change: 1985-2003

Category of Commodity	Export Volume (Unit: Billion RMB, 1990 Constant Price)[1] Data between Parentheses: Share of Total Export Volume (Percentage)			Ratio of 2003 Export Volume to 1985 or 1995 Export Volume[3]
	1985[2]	1995	2003	
Total	113.8	694.0	1914.2	16.8
Live Animals & Animal Products	4.5 (4.0)	20.9 (3.0)	23.0 (1.2)	5.1
Vegetables; Fruits and Cereals	10.3 (9.1)	19.3 (2.8)	33.1 (1.7)	3.2
Animal and Vegetable Oils;	0.6 (0.5)	2.1 (0.3)	0.6 (0.0)	1.0
Food; Beverages; Tobacco	3.2 (2.8)	21.6 (3.1)	33.5 (1.8)	10.3
Minerals	29.7 (26.1)	31.4 (4.5)	55.6 (2.9)	1.9
Chemicals and Related Products	5.7 (5.0)	39.3 (5.7)	80.9 (4.2)	14.3
Plastics and Rubber Products[3]	N.A.	20.0 (2.9)	54.7 (2.9)	*2.7*
Leather and Furs Products	**0.5 (0.4)**	**26.3 (3.8)**	**50.6 (2.6)**	**99.6**
Wood and Wooden Products[3]	N.A.	10.0 (1.4)	19.0 (1.0)	*1.9*
Paper and Paper Products[3]	N.A.	5.2 (0.7)	13.2 (0.7)	*2.6*
Textile Products	26.8 (23.5)	167.4 (24.1)	320.4 (16.7)	12.0
Footwear	**1.1 (0.9)**	**38.1 (5.5)**	**68.3 (3.6)**	**63.8**
Cement, Ceramic and Glass Products	**0.9 (0.8)**	**12.4 (1.8)**	**30.3 (1.6)**	**32.1**
Pearls; Precious Stones and Precious Metal[3]	N.A.	8.2 (1.2)	14.4 (0.8)	*1.8*
Base Metals Products	**1.8 (1.6)**	**56.4 (8.1)**	**109.7 (5.7)**	**61.9**
Machinery; Electric Equipment and Electronic Products	**1.5 (1.3)**	**129.1 (18.6)**	**752.7 (39.3)**	**497.0**
Transportation Equipment	**1.1 (1.0)**	**19.1 (2.8)**	**68.1 (3.6)**	**63.0**
Optical Products and Precision Instruments Products	**0.3 (0.2)**	**21.9 (3.2)**	**57.2 (3.0)**	**215.0**
Others	17.8 (15.7)	45.4 (6.5)	128.7 (6.7)	7.2

Source: Source: Various issues of *China Statistical Yearbook.*

Note: 1. The export volume reported in *China Statistical Yearbook* is with the unit of 100 million US Dollars. The RMB constant price export value is attained by multiplying the US Dollar value by annual average exchange rate and then dividing the result by GDP deflator. Annual average exchange rate is from various issues of *China Statistical Yearbook.* The GDP deflator is provided by the World Bank.

2. The export volume data of 1985 in *China Statistical Yearbook* are reported in line with the classification which is not consistent with that of the 1995 afterwards data. For instance, the 1995 afterwards data of Cereals and Cereals Products are reported in two different categories, namely a) Vegetables, Fruits and Cereals and b) Food, Beverages, Liquor and Vinegar, Tobacco and Tobacco Substitutes. The 1985 and 1990 data of Cereals and Cereals Products export volume are reported in the single category, i.e. Food and Edible Live Animal. The authors harmonize the 1985 and 1990 data according to the classification system of the 1995 afterwards data. The methodology is halving the amount of the 1985 and 1990 data and reporting each half in the two different categories of the 1995 afterwards data, respectively.

3. The Ratio of the volume of 2003 to the volume of 1995 (italic text) is presented when the data of several categories of commodity are not available for the year of 1985.

If the firm in Figure 5.1 increases its scale through expansion in the domestic market, it could naturally benefit from economies of scale in production to push down the average cost curve AC_w. Large firms are more likely to obtain lower cost financing services, hold more power in negotiation with upper-stream suppliers, and act more resiliently in the fluctuating international market (Wagner, 1995). However, Bonaccorsi (1992) contends that the relationship between the size and export intensity of a firm should not be generalized because the decision to export or not to export depends, to some extent, on the strategies of the firm. For example, some small firms have been found to be active in their international niche markets. Thus, to test the influence of size on export performance, we use the ratio of the number of employees of a firm to the number of the employees of the firm which hires most employees in the particular four-digit sector as a measure of the scale of a Chinese manufacturing firm.

To enhance the quality of its products, improve the production process, and ameliorate the management, a firm could enhance its R&D and innovation capacity, which would in turn reduce production costs (Wakelin, 1998). However, manufacturing firms in different sectors do not rely on R&D to acquire technology or to enhance their productivity in the same way. In his paper on innovation in British manufacturing industries, Pavitt (1984) concluded that in scale-intensive sectors such as metal manufacturing and vehicles, firms generally tend to develop their own process technology. In textile firms, however, most process innovations come from suppliers. Therefore, R&D intensity does not accurately measure technological upgrading efforts in certain manufacturing sectors, particularly in low-technology sectors (von Tunzelmann and Acha, 2005). Other important contributors to innovation efforts include design, engineering development and experimentation, adoption-related learning activities, and exploration of markets for new products (Smith, 2005). Thus, new product intensity which represents product innovation of a firm and R&D intensity enter our regressions, which will provide a more accurate estimation of the impact of R&D and innovation on the export competitiveness of Chinese manufacturing firms.

In Figure 5.1, the assumption that the average production cost AC_w is higher than international market price is not at all an extreme case. The costs involved for potential exporters to enter the international market is normally high due to the difficulty of obtaining information about foreign markets and setting up distribution channels to reach foreign clients (Keesing, 1983; Abdel-latif, 1993). In their study of Mexican manufacturing sectors, Aitken et al. (1997) found that a domestic plant is more likely to export if it is located near a multinational firm. They suggest that the presence of foreign-owned enterprises facilitates the access of domestic firms to information and technology and helps them establish distribution channels in foreign markets. To some degree, the activity of foreign investors enhances the export prospects of local firms. At the same time, while thousands of foreign investors set up manufacturing plants in China, they also bring knowledge about foreign markets to their local joint venture partners. Foreign investors' production technology, management skills, and business development strategies certainly lower the export costs of local collaborators. Therefore, we expect that the coefficient of the foreign capital intensity variable will be significant in the econometric estimation.

Previous research on the relationship between domestic market structure and export performance has reached ambiguous conclusions about export performance, so predicting whether a firm's export performance is positively affected by competition has been difficult. Caves and Jones (1973) contended that domestic collusion and limits on domestic competition are associated with high international competitiveness. In contrast, Porter (1990) cited the case of the Japanese fax machine industry that supported his "domestic rivalry" hypothesis, which states that the most important source of international competitiveness comes from domestic pressure. After all, domestic competition forces firms to innovate, resulting in rapid cost reduction. Porter's argument built on Shumpeter's theory that the small scale, entrepreneurial type of firm as the driving force of innovation (Schumpeter, 1939). Evidence supporting Porter's hypothesis can be found in Glejser et al. (1980). In their research, the Herfindahl-Hirschman Index of exporting firms in Belgium is negatively correlated with their exporting propensity. Similarly, based on the United States food manufacturing industries, Kim and Marion (1997) argued that net export share is negatively related to industry concentration. In order to test whether the above mentioned hypotheses are valid in the context of a fast-growing export country such as China, we include the Herfindahl-Hirschman Industrial Concentration Index (HHI) in the econometric model.[20] A larger HHI indicates weaker competition in the industry. The definitions of

[20] In empirical studies, the K-firm Concentration Ratio (C_k) is also widely applied to evaluate the industrial concentration. We prefer the Herfindahl-Hirschman Index simply because it can more

all dependent and explanatory variables of the econometric analysis are listed in Table 5.2.

5.2 Data, Econometric Specifications and Model Selection[21]

The primary data used in this study were collected from Chinese manufacturing enterprises whose added values were larger than five million RMB.[22] The database that was constructed by China's National Bureau of Statistics included 135,923 firms in the 2000 data, 146,180 in the 2001 data, 155,403 in the 2002 data, and 171,349 in the 2003 data. Each firm was assigned an invariant code in the database. Information for every firm, such as geographical location at the provincial level, the sector where it operates (a four-digit sector level), and the ownership status, was well recorded. More than 50 statistical indicators of the dataset were classified into five categories: output indicators, capital indicators, assets and liabilities, profits, and remuneration indicators. Because of exit and entry, we were able to use the data from only 95,517 firms, whose data existed for the three consecutive years from 2001 to 2003. We do not include the 2000 data in this analysis since the R&D indicator is not available for that year.

Table 5.2: The Variables

Variable	Name	Definition and Note
Y	Export Intensity	Export Value/Sales Value
X_1	Unit Labor Cost	Employee Compensation Value/Added Value
X_2	Firm Size	Number of Employees/ Number of Employees of the Firm which Hires Most Employees in the Particular Four-digit Sector
X_3	R&D Intensity	R&D Expenditure/Added Value
X_4	New Product Intensity	New Product Output Value/Total Output Value
X_5	Foreign Capital Intensity	Received Capital from International Investors (Including Hong Kong, Macau and Taiwan Investors)/All Received Capital
X_6	Herfindahl-Hirschman Industrial Concentration Index (HHI)	$\sum_{j=1}^{n}$ (Market Share (Percentage) of j Firm in the Specific Industry at Four Digit Sector Level)^2,
$X_{7,}\ldots X_{34}$	Sector Dummy Variables	Variables represent the 29 two digit sectors.
$X_{35,}\ldots X_{64}$	Province Dummy Variables	Variables represent the 31 provinces.
X_{65} and X_{66}	Year Dummy Variables	Variables represent the 3 years.

thoroughly capture the information carried by the large number of observations in our database. The difference between the results of the Herfindahl-Hirschman Index and the K-firm Concentration Ratio can be read in Sleuwaegen and Dehandschutter (1986).

[21] The econometric results in the chapter are obtained through the software of Stata 8.2.

[22] According to the Chinese Industry Enterprise Classification Standard (2003 version), enterprises with revenue less than 30 million RMB per year are classified as small firms. Therefore, apart from encompassing large and medium manufacturing firms, our database includes a large number of small manufacturing firms in China.

The dependent variable Y in this study is export intensity, namely the export value divided by sales value. This type of dependent variable is known as a censored dependent variable; that is, the values of the variables in a certain range are all reported as a single value, e.g., zero. The conventional linear regression method is not able to distinguish the difference between the non-linear "zero" observations and the continuous observations. Therefore, the following tobit model is a good candidate for estimating the data.

(1) $$Y^{*} = a + X^{'}\beta + \varepsilon$$

With ε ~ IIN $(0, \sigma^2)$ and

(2) $$Y = Y^{*} \text{ if } Y^{*} > 0$$
$$= 0 \text{ otherwise,}$$

where Y^{*} can be understood as the unobserved "export competence" of the firm. For the exporting firm, Y^{*} is equal to the observed export intensity Y; for the firm that does not export, Y^{*} is not observed, and Y is reported as zero. Equation (2) can be estimated by the maximum likelihood estimation.

Cragg (1971) proposed an alternative two-stage model as an unrestricted form against the tobit model that could be understood as a restricted form. The first-stage specification is a probit model that utilizes the entire data set and examines whether the firms export. The second-stage specification is a truncated model that analyzes only the data of exporting firms, for which dependent variables are greater than zero. Applying the rationale of designing a two-stage specification (Lin and Schmidt, 1984) to our case, we argue that the impact of the explanatory variables on whether the firms export and how much they export could differ. However, the difference is not detected in the tobit model, but could be revealed in the two-stage specification.

To choose between the tobit model and the two-stage model, a likelihood ratio statistic is computed using

(3) $$\lambda = -2[\log L_T - (\log L_P + \log L_{TR})],$$

where L_T, L_P, L_{TR} are likelihoods for the tobit model, the first-stage probit specification, and the second-stage truncated specification, respectively. The large sample distribution of λ is chi-squared, with degrees of freedom equal to the number of restrictions imposed. In our function, the degrees of freedom are 67.

We run the regression on the explanatory variables with one-year and two-year lag times at the expense of losing a proportion of observations to provide a more robust estimation of the causal relationship. The impact of its characteristic on the export performance of a firm may be diverse across different ownership status and industry sectors. Taking the analysis of general manufacturing firms as a point of departure, we divide the data into two ownership groups: domestic firms and foreign firms, including Hong Kong, Macau, and Taiwan-funded enterprises, according to the ownership status of the firms recorded in the database. Identical regression is run on these two groups of data to obtain the comparative results. Similarly, the comparative analyses are also implemented on the labor-intensive (i.e., textile, wearing apparel, leather, furniture, toys, and miscellaneous products) and the high-tech sectors (i.e., aircraft, pharmaceuticals, electronic and communication equipment, and precision instruments and office machinery).[23]

Table 5.3 provides the summary statistics of the data and variables. Around one-third of the Chinese manufacturing firms examined in this study exported in the period of 2001-2003. Less than one-quarter of them were foreign-owned. The statistic summary of the variables reveal that 75 percent of the Chinese manufacturing firms did not conduct R&D or launch the new products in our observation period.

[23] The classification of the labor-intensive and high-tech sectors is seen in Table 5.8 in the end of this Chapter. Table 5.8 also presents the harmonization of manufacturing sectors and product standards ISIC Rev. 3.1, SITC Rev. 3, and Chinese GB/T 4754-2002, which is used in our database. The manufacturing sectors such as food products, beverages and tobacco (ISIC code 15 and 16) and wood, pulp, paper, paper products, printing and publishing (ISIC code 20, 21, 22) are included in the low-technology industries in the OECD's classification, but they are not included in the labor-intensive sectors examined in this paper. China's competitiveness in these sectors is not as overwhelming as in the other low-technology sectors such as textile, footwear, furniture and toy etc. Our classification of the labor-intensive sectors is justified by the econometric analysis result shown in Table 5.4, in which the industry sector dummy variable of the textile, footwear, furniture and toy sectors are significant.

5.3 Estimation Results and Discussion

According to the estimation results (Tables 5.4, 5.5, and 5.6), the values of λ in no lag, one-year lag, and two- year lag models are all much greater than the chi-square statistics of the degree of freedom of 67 at the 99 percent level, which is 96.83. The tobit specification is accordingly rejected at the 99 percent level. Thus, we report only the result of the probit specification, which discloses the determinants of the exporting probability of a firm and the result of a truncate specification, which denotes the factors affecting the export intensity of a firm. Accordingly, if a firm is considered competitive, it either has higher probability of exporting or higher export intensity.

A theoretical analysis based on Figure 5.1 shows that reducing labor costs leads to international competitiveness. However, our empirical analysis demonstrates that unit labor cost does not determine whether Chinese manufacturing firms could export, as nearly all of its coefficients are insignificant in the probit specifications and significantly positive in the truncate specifications, which means that reducing unit labor cost doesn't help firms enter foreign markets. Rather, among exporting firms, those spending more on compensation export more. The positive coefficients of unit labor cost in the analyses of export determinants are not uncommon since they appear in several previous studies. Braunerhjelm (1996) found R&D expenditures and investment in skilled labor have a positive effect on the export intensity of Swedish firms, while cost factors have no impact. He interpreted this finding as indicating that the international competitiveness of a firm depends on investment in knowledge, not on cost reductions. Wakelin (1998) argued that the reason that unit labor cost is positively associated with the exporting possibility of British innovating firms is that the firms exporting higher quality products are less price sensitive. Van Reenen (1996) suggested that employees could be better compensated when firms achieved abnormally high profits from their export business. The theoretical reasoning of Van Reenen (1996) could explain our finding that no link between unit labor cost and export probability exists, given the fact that the data show the profit-to-sales ratio of exporting firms is 5.44 percent higher than that of a non-exporting firm, which is 4.68 percent. For Chinese manufacturing firms, factors such as cooperation with foreign investors and product innovation capability, which will be discussed below, are stronger determinants of export competitiveness than labor costs.

Table 5.3: Summary Statistics

Number of the Firms							
Year		Exporting Firms	Not-Exporting Firms	Domestic Firms	Foreign Firms	Firms in the Labor-intensive Sectors	Firms in High-technology Sectors
2001		29781	65735	72884	22622	20440	6632
2002		30838	64679	72806	22701	20405	6637
2003		31054	64464	72774	22730	20161	6902

Variables								
Year		Export Intensity	Unit Labor Cost	Firm Size	R&D Intensity	New Product Intensity	Foreign Capital Intensity	Herfindahl-Hirschman Industrial Concentration Index (HHI)
2001	Mean	.196	.410	.070	.006	.032	.173	.029
	75^{th} Percentile	.155	.429	.071	0	0	0	.034
	Standard Deviation	.360	2.89	.126	.231	.140	.342	.047
2002	Mean	.201	.497	.071	.005	.031	.174	.029
	75^{th} Percentile	.184	.420	.072	0	0	0	.034
	Standard Deviation	.361	20.1	.126	.046	.136	.344	.046
2003	Mean	.200	.444	.066	.008	.030	.175	.028
	75^{th} Percentile	.192	.415	.067	0	0	0	.031
	Standard Deviation	.360	4.17	.119	.753	.133	.346	.043

Table 5.4: Estimation Result: General Manufacturing Firms[1]

	No Lag Probit	One Year Lag Probit	Two Years Lag Probit	No Lag Truncate	One Year Lag Truncate	Two Years Lag Truncate
Unit Labor Cost	2.39E-4(3.31E-4)	-4.27E-4(6.09E-4)	2.60E-3(2.06E-3)	1.94E-3(4.84E-4)***	2.31E-3(5.67E-4)***	1.32E-3(6.29E-3)**
Firm's Size	2.09(.0234)***	2.03(.0280)***	2.00(.0396)***	-.214(.0107)***	-.204(.0130)***	-.219(.0186)***
R&D Intensity	1.44E-3(7.68E-3)	.0646(.0392)*	.0461(.0464)	-.0187(8.54E-3)**	-.0199(9.20E-3)**	-8.18E-3(6.36E-3)
New Product Intensity	.784(.0191)***	.669(.0231)***	.607(.0323)***	-.374(.0118)***	-.382(.0147)***	-.384(.0208)***
Foreign Capital Intensity	1.30(8.65E-3)***	1.30(.0107)***	1.30(.0151)***	.177(.00381)***	.174(.00469)***	.163(6.69E-3)***
HHI	-.180(.0669)***	3.19E-3(.0787)	.135(.109)	-.370(.040)***	-.410(.0481)***	-.350(.0667)***
Two-digit Industry Sector Dummy Variables Whose Coefficients are Significant	Textiles; Wearing Apparel and Other Fiber Products; Leather, Fur, Down and Related Products; Wood, Bamboo, Cane, Palm, and Straw Products; Furniture; Culture, Education and Sport Products; Chemicals and Chemical Products; Pharmaceutical Products; Rubber Products; Smelting and Pressing of Non-ferrous Metals; Metal Products; General Machinery; Electrical Equipment; Electronic and Communication Equipment; Precision Instruments and Office Machinery; Miscellaneous Products.			Wearing Apparel and Other Fiber Products; Leather, Fur, Down and Related Products; Bamboo, Cane, Palm, and Straw Products; Furniture; Culture, Education and Sport Products; Miscellaneous Products.		
Province Dummy Variables Whose Coefficients are Significant	Fujian, Guangdong, Jiangsu, Liaoning, Shandong, Shanghai, Tianjin, Zhejiang			Fujian, Guangdong, Hainan, Heibei, Liaoning, Shandong, Shanxi, Tianjin, Zhejiang		
Number of Observation	286554	190869	95445	91674	61893	31056
Log Likelihood	-130065.9	-87225.7	-43728.6	-18172.3	-12141.1	-6084.8
Tobit Likelihood	-162869.8	-108920.3	-54557.5			
λ	29263.2	19107	9488.2			

Note: 1. *** denotes significance at 1% level, ** denotes significance at 5% level, * denotes significance at 10% level.

Table 5.5: Estimation Result: Foreign and Domestic Firms[1]

	No Lag Probit	One Year Lag Probit	Two Years Lag Probit	No Lag Truncate	One Year Lag Truncate	Two Years Lag Truncate
			Foreign Firms			
Unit Labor Cost	-2.12E-4(2.97E-4)	-2.95E-4(3.82E-4)	8.95E-3(3.78E-3)**	1.53E-3(4.82E-4)***	1.85E-3(5.23E-4)***	1.07E-3(5.72E-4)*
Firm's Size	1.73(.0555)***	1.78(.0686)***	1.80(.0999)***	.0794(.0124)***	.0919(.0152)***	.0876(.0223)***
R&D Intensity	-2.89E-3(.0253)	-2.73E-3(.0277)	.101(.155)	-5.62E-3(5.32E-3)	-8.11E-3(5.64E-3)	-2.79E-3(5.40E-3)
New Product Intensity	.346(.0389)***	.199(.0467)***	.205(.0638)***	-.268(.0143)***	-.270(.0178)***	-.240(.0244)***
Foreign Capital Intensity	.652(.0167)***	.661(.0209)***	.671(.0301)***	.120(5.82E-3)***	.116(.00725)***	.112(.0106)***
HHI	.174(.127)	.0900(.153)	.204(.216)	-.251(.0448)***	-.286(.0542)***	-.248(.0765)***
Number of Observation	68053	44796	22111	44610	29623	14726
Log Likelihood	-36906.6	-24141.3	-11857.3	-9969.5	-6623.2	-3345.4
Tobit Likelihood	-53225.1	-34786.7	-17056.6			
λ	12698	8044.4	3707.8			
			Domestic Firms			
Unit Labor Cost	1.13E-3(2.51E-3)	9.73E-4(3.50E-3)	4.06E-4(5.31E-3)	.0130(2.40E-3)***	.0203(3.42E-3)***	.0110(4.29E-3)**
Firm's Size	2.20(.0261)***	2.13(.0313)***	2.09(.0442)***	-.556(.0212)***	-.545(.0257)***	-.571(.0362)***
R&D Intensity	.235(.0645)***	.401(.0867)***	.311(.127)**	-1.90(.138)***	-1.96(.172)***	-2.35(.259)***
New Product Intensity	.911(.0219)***	.809(.0266)***	.730(.0377)***	-.364(.0198)***	-.386(.0249)***	-.435(.0367)***
Foreign Capital Intensity	.995(.0396)***	.883(.0517)***	.731(.0770)***	.158(.0205)***	.128(.0278)***	.188(0423)***
HHI	-.342(.0806)***	-.0481(.0934)	.110(.129)	-.595(.0785)***	-.605(.0924)***	-.490(.124)***
Number of Observation	218464	144898	72147	218464	31715	15773
Log Likelihood	-90691.4	-60746.6	-30366.0	-5820.3	-3776.2	-1788.8
Tobit Likelihood	-103962.6	-69426.4	-34667.1			
λ	14901.8	9807.2	5024.6			

Note: 1. *** denotes significance at 1% level, ** denotes significance at 5% level, * denotes significance at 10% level.

Table 5.6: Estimation Result: Manufacturing Firms in Labor-intensive and High-technology Sectors[1]

	No Lag Probit	One Year Lag Probit	Two Years Lag Probit	No Lag Truncate	One Year Lag Truncate	Two Years Lag Truncate
			Firms in Labor-intensive Sectors			
Unit Labor Cost	2.11E-4(9.65E-4)	2.26E-4(1.12E-3)	.0726(.0135)***	1.97E-3(7.43E-4)***	7.12E-3(1.39E-3)***	4.51E-3(1.65E-3)***
Firm's Size	2.83(.0702)***	2.74(.0835)***	2.54(.115)***	-.0667(.0137)***	-.0714(.0169)***	-.0851(.0249)***
R&D Intensity	.526(.396)	.558(.467)	-.0935(.320)	-4.53E-3(4.87E-3)	-.0147(5.35E-3)***	-9.36E-3(5.59E-3)*
New Product Intensity	.921(.0650)***	.624(.0761)***	.419(.102)***	-.227(.0166)***	-.219(.0207)***	-.195(.0293)***
Foreign Capital Intensity	.979(.0167)***	.958(.0208)***	.966(.0300)***	.0708(4.33E-3)***	.0686(5.39E-3)***	.0625(7.76E-3)***
HHI	-4.55(.206)***	-4.80(.260)***	-4.81(.403)***	-.847(.0690)***	-.958(.0899)***	-1.06(.141)***
Number of Observation	61006	39755	19400	35764	23712	11585
Log Likelihood	-33711.8	-21904.8	-10720.9	-6084.0	-4141.0	-2075.4
Tobit Likelihood	-50197.5	-32631.5	-15967.8			
λ	20803.4	13171.4	6343			
			Firms in High-technology Sectors			
Unit Labor Cost	5.19E-3(4.31E-3)	2.62E-3(6.32E-3)	3.03E-3(8.92E-3)	2.57E-3(1.37E-3)*	4.17E-3(2.19E-3)*	1.90E-3(2.73E-3)
Firm's Size	2.20(.0804)***	2.20(.101)***	2.16(.148)***	-.0250(.0280)	2.55E-4(3.63E-2)	-.0451(.0540)
R&D Intensity	-.122(.0618)**	-.274(.179)	.0202(.0925)	-.0456(.0430)	-.772(.148)***	.0242(.0289)
New Product Intensity	.411(.0433)***	.322(.0535)***	.255(.0753)***	-.179(.0238)***	-.188(.0305)***	-.221(.0443)***
Foreign Capital Intensity	1.33(.0283)***	1.29(.0359)***	1.29(.0523)***	.441(.0138)***	.433(.0178)***	.410(.0263)***
HHI	-2.08(.180)***	-2.02(.229)***	-1.59(.335)***	-.251(.0842)***	-.127(.104)	.0311(.144)
Number of Observation	20153	12613	5997	8717	5434	2615
Log Likelihood	-10048.0	-6350.9	-3046.4	-1211.4	-671.85	-333.6
Tobit Likelihood	-12085.4	-7517.9	-3605.6			
λ	1652	990.3	451.2			

\\Note: 1. *** denotes significance at 1% level, ** denotes significance at 5% level, * denotes significance at 10% level

The coefficients of the size of a firm are significantly positive in all probit specification results, which demonstrates that larger manufacturing firms in China have a higher probability of exporting. Nevertheless, the results of the truncate specification indicate that the scale is negatively associated with the export intensity of exporting firms, except for foreign firms and firms in high-tech sectors. The no-lag truncate function estimation result reveals that for a domestic and labor-intensive firm, one percent increase of the firm size variable value, i.e. the ratio of the number of employees to the number of employees of the firm which hires most employees in the particular four-digit sector, leads to a 0.556 percent and a 0.0667 percent decrease in export intensity, respectively. In contrast, for the foreign firms one percent increase of the firm size variable value could increase the export intensity by 0.794 percent. This indicates that the smaller domestic exporting firms and the smaller firms in the labor-intensive sectors export relatively more than larger ones. The sharp contrast between the coefficients of the probit specification and the truncate specification further justifies the two-stage specification, which discriminates between the impact of the explanatory variables on whether a firm exports and how much it exports.

Except for domestic firms, the R&D investment contributes to neither the export probability nor the export intensity of a manufacturing firm. We observe a statistically significant causal relationship between R&D investment and export probability of domestic firms, but the truncate specification results show that R&D intensity does not lead to the export intensity of domestic firms. Bearing in mind the fact that China surpassed the United States and the European Union to become the biggest exporter of information and telecommunications technology goods in 2004 (OECD, 2005), surprisingly, we fail to find evidence that R&D investment led to the stellar export performance of the high-tech firms. According to the definition of OECD (2003), high R&D investment intensity, namely the high ratio of R&D expenditure to value-added, is the hallmark of high-tech sectors. Therefore, how is the success of high-tech Chinese firms in global markets unrelated to their investment in R&D? We suggest processing trade as an explanation to this paradox.

Research by Lemoine and Unal-Kesenci (2004), China's National Bureau of Statistics (2005), and Fung (2005) has attributed the recent expansion of China's exports in machinery, electrical equipment, and electronic products, in large part to processing trade and the global division of labor, especially in East Asia. For many producers in high income economies such as Japan, South Korea, and Taiwan, transferring manufacturing departments to low-cost countries is imperative if they are to retain market share among strong competition. They have shipped high value-added components (normally developed in their homelands) to China for assembly, taking advantage of low production costs there, and then exported the end products through their affiliates to Western markets. According to a report by the Chinese Ministry of Commerce, the share of processing trade export accounted for 55 percent of China's total exports in 2004 (Xinhua Net, 2004).

Foreign-funded enterprises controlled more than 70 percent of China's high-tech exports in the last several decades. Their share in total high-tech exports reached 87 percent in 2002 (Table 5.7). China's Ministry of Commerce reported that of the approximate 400 billion US Dollars in high-tech export products from China in 2005, less than ten percent of the products were exported with the brand name of the manufacturer or with independent intellectual property rights (Xinhua Net, 2005). Furthermore, both in 1995 and 2002, the average R&D intensity of all high-tech firms in China was higher than that of foreign-funded firms (Table 5.7), indicating that domestic firms were more committed to R&D investment than foreign firms. This information, derived from the data of *China Statistics Yearbook on High Technology Industry* is fully supported by the results of our analysis. As Gilboy (2004) asserted, Chinese industrial firms were deeply dependent on designs, critical components, and manufacturing equipment they imported from advanced industrialized countries.

Table 5.7: Foreign Enterprises in China's High-tech Sectors: 1995 and 2002 Data[1]

		1995	2002
Total High-tech Enterprises in China	Export Volume (Unit: Billion RMB, Current Price)	112.5	602
	R&D Expenditure/ Added Value (Percentage)	1.7	5.0
Foreign High-tech Enterprises	Export Volume (Unit: Billion RMB, Current Price)	83.0	523.0
	R&D Expenditure/Added Value (Percentage)	0.5	3.0
Share of Foreign Enterprises' High-tech Export in Total High Technology Export in China (Percentage)		73.8	86.9

Source: *China Statistics Yearbook on High Technology Industry 2003*.

Note: 1. Foreign enterprises include Chinese-foreign equity joint ventures, contract joint venture and wholly foreign-invested enterprises.

Because foreign firms and their subsidiaries dominated China's high-tech export industry and invested less in R&D than domestic firms, the average R&D intensity of Chinese high-tech sectors was much lower than that of their counterparts in advanced OECD countries. According to our data, 75 percent of the manufacturing firms in China did not conduct R&D or launch new products in the period of 2001-2003 (see Table 5.3). The R&D intensity of China's electronic and communication equipment and precision instruments and office machinery was 2.47 percent and 2.15 percent in the 2001-2003 period, respectively. However, the R&D intensity of the radio, TV and communications equipment sector in the 12 OECD countries was 22.4 percent (OECD, 2003, p.156).[24] In these OECD countries, the R&D intensity of the office, accounting, and computing machinery and medical, precision, and optical instrument sectors was 15.1 percent and 11.9 percent, respectively, compared with that of China, which was 2.15 percent. The meager R&D investment in China's high-tech sectors is the principal reason for the appearance of an insignificant coefficient of R&D intensity in our estimation results.

Although the coefficients of the new product intensity are all significantly positive in probit specification results, they are universally significantly negative in the truncate specification results. This finding indicates that higher new product intensity increases the probability that Chinese firms will enter international markets. However, firms exporting more exhibit a lower ratio of new product value to total production value, which shows new product intensity as a "qualification threshold" for the Chinese manufacturing firms to enter the export business. Firms with higher new product intensity are more likely to export, but for those that pass the threshold, their export intensity turns out to be negatively associated with new product intensity. International user-producer interaction, we argue, may explain the finding that product innovation leads to a greater likelihood that Chinese firms will enter international markets. The firms themselves might not be pressured to innovate as frequently if they supply a stagnant market, but if they have to meet varying demand throughout the world, they are likely to launch new products more rapidly (Lundvall, 1992).

[24] The 12 OECD countries are United States, Canada, Japan, Denmark, Finland, France, Germany, Ireland, Italy, Spain, Sweden and United Kingdom.

Foreign capital intensity is universally positively correlated with export competitiveness according to the results of various specifications, which denotes that knowledge about foreign markets, technology, and management skills brought in by foreign investors of joint ventures are critical to firms' expansion in international markets. The foreign capital to total capital ratio, i.e., foreign equity share, has a larger impact on the domestic firms since the coefficients of the domestic firms are greater than those of the foreign firms. Similarly, cooperation with foreign investors leads to higher export probability and export intensity in high-tech sectors than in labor-intensive sectors. This finding also supports our argument that high-tech sectors in China are more dependent on foreign investors than labor-intensive sectors, in which Chinese firms possess an overwhelming comparative advantage.

The fiercer competition plays a significant role in aiding firms in the labor-intensive and high-tech sectors to start to expand their business outside of China, but its effect on foreign and domestic firms is not statistically significant, indicating that the effect of sector competition is distinct in the labor-intensive and the high-tech sectors, but not in the other sectors. When we group the firms by their ownership status, the firms from different sectors are mingled so that the effect of competition could not be distinguished. Results show that the coefficients of HHI are consistently significantly in the truncate specification results except for the high-tech firms. Generally, competition, explained by Porter's "domestic rivalry" hypothesis, has a positive impact on the export probability of Chinese manufacturing firms in the labor-intensive and high-tech sectors. The more rigorous competition in the sector is, the more likely the firms are to export.

The significant coefficients of certain sector dummy variables in the no lag probit specification demonstrate that the Chinese manufacturing firms that are more inclined to export are in the labor-intensive and high-tech sectors such as the following: textile, garment, leather, and toy (sub-sectors in cultural, education, and sports products), and electronics and telecommunications, precision instruments, and office equipment, respectively. The results pertaining to the province dummy variables show that firms located in the eight coastal provinces of Fujian, Guangdong, Jiangsu, Liaoning, Shandong, Shanghai, Tianjin, and Zhejiang are more competitive than those located elsewhere.[25]

To sum up this chapter, we use the data of more than 95,000 Chinese manufacturing firms to explore the reasons accounting for the recent growth of the Chinese manufacturing exports. We find that product innovation, collaboration with foreign investors and fierce competition increase the probability that Chinese firms enter international market. Unit labor cost is not decisive factor determining the firms' export success. R&D investment does not contribute to China's export competitiveness either, even in high-technology sectors. Foreign manufacturing firms dominated China's high-technology product export, but they devoted less resource to R&D investment than domestic counterparts.

[25] The estimation result of sector and province dummy variables in the no lag truncate specification is not significantly different from that of the probit specification. To simplify, the sector and province dummy variable results in the remaining regressions are not reported.

Table 5.8: Harmonization of Manufacturing Sector Classification of ISIC Rev. 3.1, SITC, Rev. 3 and Chinese Industry Sector Classification GB/T 4754-2002 (Utilized in the Database)

International Standard Industrial Classification of All Economic Activities, Revision 3.1, (ISIC Rev. 3.1)	ISIC Rev. 3.1 Code	Standard International Trade Classification, Revision 3 (SITC, Rev. 3)	SITC Rev. 3 Code	Chinese GB/T 4754-2002	GB/T 4754-2002 Code
Labor Intensive Sectors where China Traditionally Holds Comparative Advantage					
Manufacture of textiles	D17	Textile fibers (other than wool tops and other combed wool) and their wastes (not manufactured into yarn or fabric)	26	Manufacture of Textiles	17
		Textile yarn, fabrics, made-up articles, n.e.s., and related products	65		
Manufacture of wearing apparel; dressing and dyeing of fur	D18	Articles of apparel and clothing accessories	84	Manufacture of Wearing Apparel and Other Fiber Products	18
		Footwear	85		
Manufacture of wearing apparel; dressing and dyeing of fur	D18	Leather, leather manufactures, n.e.s., and dressed fur skins	61	Manufacture of Leather, Fur, Down and Related Products	19
Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	D19	Travel goods, handbags and similar containers	83		
Manufacture of furniture; manufacturing n.e.c.	D36	Furniture, and parts thereof; bedding, mattresses, mattress supports, cushions and similar stuffed furnishings	82	Manufacture of Furniture	21
Manufacture of furniture; manufacturing n.e.c.	D36	Printed matter	892	Manufacture of Culture, Education and Sport Products	24
		Baby carriages, toys, games and sporting goods	894		
		Office and stationery supplies, n.e.s.	895		
		Musical instruments and parts and accessories thereof; records, tapes and other sound or similar recordings (excluding goods of groups 763 and 883)	898		
Manufacture of furniture; manufacturing n.e.c.	D36	Works of art, collectors' pieces and antiques	896	Manufacture of Miscellaneous Products	43
High Technology Sectors (OECD's Definition)[1]					
Manufacture of aircraft and spacecraft	D353	Aircraft and associated equipment; spacecraft (including satellites) and spacecraft launch vehicles; parts thereof	792	Aircraft and Spacecraft	377

Table 5.8 (Continued)

Manufacture of pharmaceuticals, medicinal chemicals and botanical products	D2423	Medicinal and pharmaceutical products	54	Medicine and Pharmaceuticals	27
Manufacture of radio, television and communication equipment and apparatus	D32	Telecommunications and sound-recording and reproducing apparatus and equipment	76	Manufacture of Electronic and Communication Equipment	41
Manufacture of office, accounting and computing machinery	D30	Office machines and automatic data-processing machines	75	Manufacture of Precision Instruments and Office Machinery	42
Manufacture of medical, precision and optical instruments, watches and clocks	D33	Professional, scientific and controlling instruments and apparatus, n.e.s.	87		
		Photographic apparatus, equipment and supplies and optical goods, n.e.s.; watches and clocks	88		

Note: 1. OECD’s high technology definition is seen in OECD (2003, p.156).

Chapter 6 Manufacturing Dynamics and Technological Catching-up: The Case of Guangdong Province and Hong Kong SAR[26]

6.1 The Economic Relationship between Hong Kong and Guangdong in Recent History

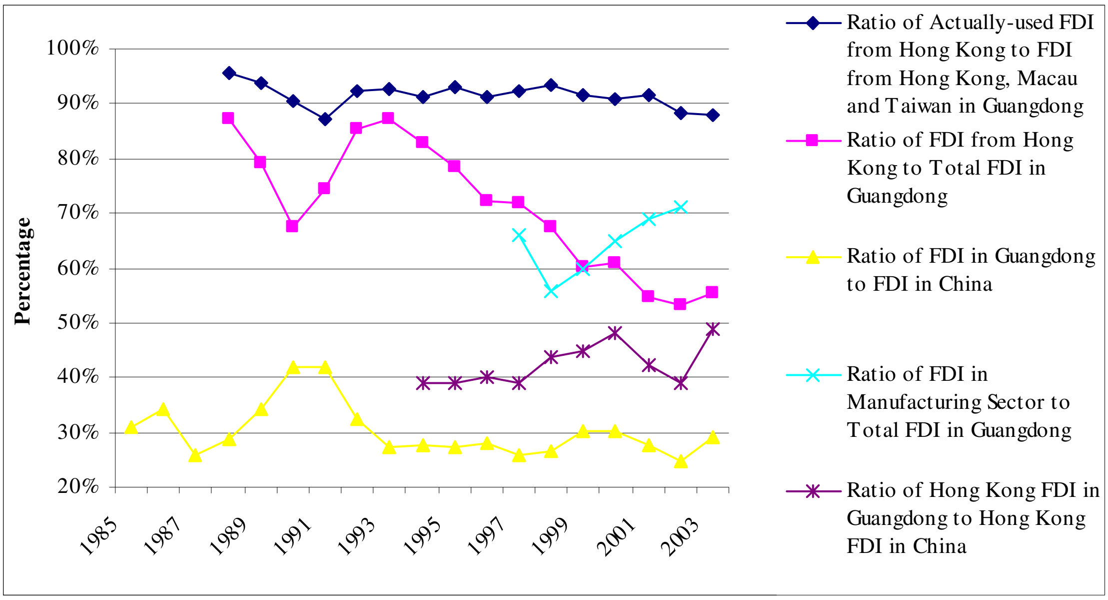
Around one-third of FDI to China over the period 1985-2003 went to Guangdong province. Guangdong was able to attract 30 percent of China's total FDI in large part because of its geographical and cultural proximity to Hong Kong, Macau, and Taiwan (hereafter referred to as HKMT), all three of which have invested heavily in China over the past 25 years. From Hong Kong's perspective, Guangdong province is the most important investment destination in China. Since the mid 1990s, Hong Kong-based entrepreneurs have allocated almost half of their investments in China to Guangdong province (See Figure 6.1). China's modernization program, which began in 1979, deeply affected manufacturing industries in both Hong Kong and Guangdong. The opening-up process in Southern China (featuring Special Economic Zones) catalyzed the transformation of industrial sectors in Hong Kong and Guangdong. It was during this opening-up period (after the late 1970s) that manufacturing firms in Hong Kong began to worry about their gradually eroding international competitiveness because of increasing labor costs in the colony. China's open-door policy, coupled with economic reforms, not only provided a large production hinterland and a much cheaper labor force for Hong Kong's manufacturers, but also generated abundant business opportunities for a wide range of service activities.[27]

The most striking change triggered by the opening-up process in Hong Kong's economy was that, as the role of manufacturing decreased, the role of the services sector

[26] This chapter is adapted from unpublished manuscript, Huang, Can; Sharif, Naubahar, 2006. Manufacturing Dynamics and Technological Catching-up: The Case of Guangdong Province and Hong Kong SAR. The manuscript was presented in The 2nd ASIALICS International Conference on Innovation Policy and Management in Changing Asia, Korea, April 17-20, 2005 and The 32nd Annual Conference of the European Association for Research in Industrial Economics, Porto, Portugal, September 1-4, 2005.
[27] These included, in particular, freight transport, storage, telecommunications, banking, real estate development, and professional services such as legal, insurance, and accounting.

increased. At its peak in the mid-1980s, the manufacturing sector in Hong Kong employed 41.7 percent of the active labor force, but by 1995 it employed only 12.5 percent (Hong Kong. Census and Statistics Department, 1985-2005; Berger and Lester, 1997: 9). The contribution made by manufacturing to Hong Kong's GDP dropped from 23.6 percent in 1980 to just 4.6 percent in 2002; concurrently, the contribution made by services to Hong Kong's GDP rose from 67.3 percent to 87.4 percent (see Table 6.1) over the same period.

Figure 6.1: Foreign Direct Investment in Guangdong, 1985-2003



Source: Various issues of *Guangdong Statistical Yearbook* and *China Statistical Yearbook*.
Note: 1. When calculating the "Ratio of Hong Kong FDI in Guangdong to Hong Kong FDI in China" for the period of 1994-1997, the authors adopt the FDI data, which include data reflecting foreign loans and foreign non-direct investment.

Table 6.1: Percentage Contribution to GDP of Economic Activity in Hong Kong

Economic Activity/ Year	Agriculture, Fishing, Mining, Electricity, Gas and Water	Construction	Manufacturing	Services
1980	2.5	6.6	23.6	67.3
1985	3.5	5.0	22.0	69.5
1990	2.8	5.4	17.5	74.4
1995	2.6	5.3	8.3	83.7
2000	3.3	5.2	5.8	85.7
2002	3.5	4.4	4.6	87.4

Source: Hong Kong Census and Statistics Department, and Hong Kong (China), 1985-2005.

Table 6.1 underscores the magnitude of the structural adjustment in Hong Kong, and by extension in Guangdong, that took place in the decade and a half leading up to Hong Kong's handover back to China in 1997. Concomitantly, a successful model of Chinese business was flourishing in Hong Kong while controlling a large manufacturing base in Guangdong province. This organizational model, featuring Chinese family businesses, superimposes a paternalistic management structure onto a network of social and economic relationships connecting firms of many sizes (Redding, 1990). In establishing and upgrading their organizational model, Hong Kong firms have exploited their traditional strategies of imitation and followership while emphasizing the development of organizational know-how rather than formal R&D for new product development. For example, surveys have found that 60-70 percent of electronics firms in Hong Kong have succeeded by copying or modifying other products instead of initiating independent product design (Yu and Robertson, 2000). The bulk of R&D expenditure by private firms in Hong Kong is devoted to redesigning and improving products as well as to making them easier and cheaper to produce. In other words, process innovation has often taken precedence over product innovation in Hong Kong's industries.

Since the mid-1980s, Hong Kong has been the chief source of FDI in China. Hong Kong companies, or investors operating out of Hong Kong, employed at least 11 million people and owned 60,000 factories in Guangdong province in 2001 (Federation of Hong Kong Industries, 2003). Thus the migration of production facilities to Guangdong from 1979 onwards has in many ways represented growth, rather than decline, in Hong Kong's engagement in manufacturing; for political reasons, however, such growth was categorized as extraterritorial, even if it was, from a historical perspective, a reintegration into Guangdong markets. The effects on the service industries have also brought economic benefits, as most of the migration spurred further growth and increased sophistication in producer business services (Tao and Wong, 2002).

Additional statistics support the idea of closer economic integration between Hong Kong and Guangdong over the last decade: The value of exports from Guangdong to Hong Kong rose from 22.25 million US Dollars in 1995 to 42.38 million US Dollars in 2002. From 2001 onwards, 30 percent of the cargo loaded and discharged in Hong Kong's ports was related to the trade with the China, and 70 percent of that involved

Guangdong (Hong Kong, Census and Statistics Department, 2005). As noted, Hong Kong companies have been the largest source of FDI in Guangdong. In 1985, no less than 90 percent of FDI in Guangdong was invested by Hong Kong entrepreneurs. This level of FDI fluctuated in the second half of the 1980s and decreased steadily after the mid 1990s, but even as recently as 2003 approximately 55 percent of total FDI in Guangdong came from Hong Kong.

By shifting parts of their operations to China, Hong Kong industrialists vastly increased the scope of their enterprises. In 1997 Hong Kong manufacturing companies employed an estimated five million people in their plants in China, principally in Guangdong province (Berger and Lester, 1997: 10)—over five times the workforce they had employed in Hong Kong at the peak of manufacturing in the territory in 1984. Therefore, while 'Made *in* Hong Kong' manufacturing declined, 'Made *by* Hong Kong' manufacturing—manufacturing in Hong Kong-owned and managed plants in Guangdong—flourished. Furthermore, by 2003 manufacturing production services accounted for around 50 percent of Hong Kong's GDP. Approximately 1.5 million jobs involving over 40 percent of Hong Kong's labor force were related to manufacturing activities on the part of Hong Kong companies in Guangdong (Federation of Hong Kong Industries, 2003).

In summary, Hong Kong has entered, particularly in the years following 1997, a period of warming economic, political, social, and cultural ties with China. These changing conditions underscore the high degree of interdependence—both historical and present-day—of Hong Kong and Guangdong province. Not only have Hong Kong businesses been actively involved in recognizing the opportunities presented by Guangdong's abundant resources, but more recently bureaucrats and politicians have come to appreciate the magnitude of the contribution that even deeper integration can make in the future. As we observe in this paper's final section, these officials have begun translating this understanding into concrete policy initiatives.

6.2 Total Factor Productivity (TFP) and Labor Productivity Growth in Guangdong's Manufacturing Sectors[28]

To ascertain the contribution of Hong Kong's firms to productivity of Guangdong domestic manufacturing firms, we first calculate productivity growth in these firms based on two-digit sector-level data from 1997-2003. We pay special attention to two types of productivity: total factor productivity (TFP) as treated in the framework of neo-classical growth theory, and theory-free labor productivity. When attained through the growth accounting method, TFP is traditionally utilized to explain technological change at the firm, industry, and country levels. Considering the theoretical controversy surrounding the TFP concept, especially when TFP is applied to fast-growing newly industrialized economies, we calculate both TFP and labor productivity growth in this paper and explain their respective implications.[29] Because the labor productivity calculation is fairly straightforward—labor productivity equals added value divided by labor input—we concentrate in the following sub-sections on the methodology used in calculating TFP.

6.2.1 TFP Calculation Framework: Translog Production Function

Li (1999) utilizes the translogarithmic production function to analyze a panel of state factories in Guangdong province during the period 1980-1987. His research, based on firm-level data, reveals the rapid TFP growth achieved by Guangdong manufacturing firms. Following Li, we adopt the following translog function as a framework for calculating TFP growth in Guangdong manufacturing sectors.

(1) $$q = \exp[a_0 + a_k \ln k + a_l \ln l + a_t t + \frac{1}{2} b_{kk} (\ln k)^2 + b_{kl} (\ln k)(\ln l) + b_{kt} (\ln k) t + \frac{1}{2} b_{ll} (\ln l)^2 + b_{lt} (\ln l) t + \frac{1}{2} b_{tt} t^2],$$

[28] The econometric results in the chapter are obtained through the software of Stata 8.2.

[29] Young's paper (1995) on East Asia's fast-growing economies (including Hong Kong's) and Krugman's subsequent interpretation (Krugman, 1994) are based on total factor productivity. Their results have received much criticism, however, from scholars such as Chen (1997), Felipe (1999), Nelson and Pack (1999), Rodrigo (2000) and Felipe and McCombie (2003). Critics argue that assumptions underlying Young's (1995) TFP growth accounting methodology—i.e. that technological progress is exogenous, disembodied, and Hick-neutral—are too far removed from reality. Critics also argue that deriving measurements from a neo-classical production function affects the consistency of the results reached in different studies. They call for policy attention to entrepreneurship, innovation, and learning in the country's effort to catch up economically.

where q is the deflated added value, k is the deflated capital input, l is the labor input and t is the time-trend variable. Under the assumption of constant returns to scale, the parameters of Function (1) satisfy the following condition:

(2) $$a_k + a_l = 1 \quad \text{and} \quad b_{kk} + b_{kl} = b_{ll} + b_{kl} = b_{kt} + b_{lt} = 0$$

The TFP growth across discrete time periods is:

(3) $$TFP_{t-1,t} = (\ln q_t - \ln q_{t-1}) - \alpha_k (\ln k_t - \ln k_{t-1}) - \beta_l (\ln l_t - \ln l_{t-1}),$$

where α_k and β_l denote the elasticity of output with respect to capital and labor input, respectively, and

(4) $$\alpha_k = (\alpha_{k,t} + \alpha_{k,t-1})/2;$$

(5) $$\beta_k = (\beta_{k,t} + \beta_{k,t-1})/2.$$

According to α_k and β_l's definition and the assumption of constant returns to scale, we obtain $\alpha_{k,t}$ and $\beta_{l,t}$ through the following functions:

(6) $$\alpha_{k,t} = \frac{\partial \ln q}{\partial \ln k} = a_k + b_{kk}(\ln k_t) + b_{kl}(\ln l_t) + b_{kt} t$$

(7) $$\beta_{l,t} = 1 - \alpha_{k,t}$$

6.2.2 Data Collection, Variable Deflation and Production Function Estimation

Our dataset is taken from various issues of the Guangdong Statistical Yearbook. It covers 28 two-digit manufacturing sectors (shown in Table 6.9 in the end of the chapter) and also embraces four ownership groups: state-owned, collective, shareholding and foreign enterprises in the period spanning 1997-2003.[30] The first three groups only include domestic firms. Foreign enterprises are the firms registered as foreign-funded

[30] In various issues of the Guangdong Statistical Yearbook, in addition to data on the 28 manufacturing sectors, data on coal mining, petroleum and natural gas extraction, ferrous metal mining, nonferrous metal mining, nonmetal minerals mining, electricity supply, gas supply, and water supply are also consistently reported. However, private and foreign capital was denied entry in most of these industry sectors in our observation period; therefore, we do not encompass these sectors in the analysis of this chapter. Moreover, in various issues of Guangdong Statistical Yearbook, besides the data on state-owned, collective, shareholding, and foreign enterprises, the data on employee shareholding cooperative enterprises are reported as well. Due to their miniscule economic scale, however (in 2003, their gross industrial output accounted for less than 1 percent of total gross industrial output in Guangdong), we do not incorporate the ownership group comprised of employee shareholding cooperatives into the analysis.

enterprises, including joint equity ventures, contractual joint ventures and wholly foreign-owned enterprises. With reference to Jefferson et al.'s (1992, 1996) variable deflation methodology, which is designed particularly for Chinese industrial statistics data, we utilize the price deflators for gross industrial output reported in the Chinese Statistical Yearbook to obtain the deflated variable of added value.[31] The variable of capital input is deflated by the price indices of fixed-asset investment. The details pertaining to our variable deflation are elaborated in Table 6.10 in the end of the chapter.

The OLS estimation of Function (1), with standard deviation in parentheses, is as follows:

$$q = \exp[0.041_{(0.119)} + 0.522_{(0.071)} \ln k + 0.379_{(0.075)} \ln l + 0.159_{(0.045)} t + 0.020_{(0.015)} (\ln k)^2$$
$$+ 2.91E - 5_{(0.017)} (\ln l)^2 - 0.006_{(0.005)} (\ln t)^2 - 0.014_{(0.301)} (\ln k)(\ln l) + 0.0008_{(0.010)} (\ln k)t$$
$$+ 0.010_{0.011} (\ln l)(\ln t)],$$

adjusted R-square=0.89, F(9,762)=752.87, N=772. With the estimated coefficients of Equation (1) and Equations (3)-(7), we obtain the TFP growth of state-owned, collective, shareholding, and foreign manufacturing sectors in the period of 1997-2003.

6.2.3 The Catching-up in Productivity of Guangdong Manufacturing Firms

Table 6.2 shows the breakdown of the industrial gross output value of manufacturing firms in Guangdong, based on the existing ownership groups of 1997 and 2003, respectively. Shares above 60 percent are marked in bold text in the table. From 1997 to 2003, the share in industry gross output taken by foreign enterprises had increased in 24 of the total of 28 manufacturing sectors. State-owned companies expanded their shares in eight sectors. The share taken by shareholding enterprises grew in almost all sectors; in contrast, the share taken by collectively owned firms declined in all sectors. The growth in shares of output in manufacturing sectors taken by shareholding companies, as well as the decrease in shares taken by state-owned enterprises, stems mainly from the ownership reform taking place during our observation period, over the course of which many state-owned companies were transformed into shareholding companies and

[31] According to *China Statistical Yearbook* (2004, p.572), Value-added of Industry = Gross Industrial Output Value – Intermediate Input + Value-added Tax. Since there is no specific added-value deflator published in the China Statistical Yearbook, we adopt the Ex-factory Price Indices of Industrial Products as our added value deflator. Differing from us in methodology, Jefferson et al. (1992 and 1996) estimate the production function as Gross Industrial Output Value = Capital Input + Labour Input + Intermediate Input. Added-value does not enter their production function.

were publicly listed on stock exchanges. In 2003, foreign firms produced more than 60 percent of the total industrial output in 17 sectors, further securing their predominant sectoral positions in Guangdong's economy.

Even though foreign firms surpassed their domestic counterparts in Guangdong in terms of output growth, domestic enterprises gained with regard to labor productivity. As demonstrated in Table 6.3, in 1997 foreign enterprises featured higher labor productivity than domestic firms in 20 out of 28 sectors. In particular, in many of those sectors, foreign firms' labor productivity in 1997 was twice or three times that of local enterprises. Significantly, however, domestic companies had within seven years gained the lead in 16 out of 28 sectors (marked in bold text in Table 6.3). From 1997 to 2003, pressured by fierce competition from FDI-funded companies, domestic companies shrank in size while simultaneously achieving higher labor productivity growth rates and regaining the advantage in over half of Guangdong's manufacturing sectors. Table 6.4 reveals the average annual TFP growth rates for enterprises falling into four ownership groups. In every manufacturing sector, at least one domestic ownership group achieved faster TFP growth than did foreign firms (marked in bold text in Table 6.4). In several sectors—paper, printing, chemical products, pharmaceutical products, and special mechanical products—all three domestic ownership groups achieved superior levels of TFP growth as compared with foreign firms.

6.3 Identifying the Source of Manufacturing Sector Productivity Growth in Guangdong: Exploration of the Hong Kong Factor

As demonstrated in the previous section, Guangdong domestic firms gained in productivity during a time when foreign firms strengthened their dominant position in Guangdong province. The expansion of FDI, particularly the capital flush from Hong Kong, occurred at the same time as the catching-up in productivity of domestic firms. This finding leads us to ask whether this progress in manufacturing productivity in Guangdong is bolstered by economic activity generated from foreign capital inflows, the majority of which was attributable to Hong Kong entrepreneurs (see Figure 6.1). In other words, did Hong Kong firms contribute to productivity growth in Guangdong domestic firms?

Table 6.2: Percentage Breakdown of Industrial Gross Output Value in Guangdong Province, 1997 and 2003[1]

Sectors	1997				2003			
	Domestic Enterprises			Foreign Enterprises	Domestic Enterprises			Foreign Enterprises
	State-Owned Enterprises	Collective Enterprises	Shareholding Enterprises		State-Owned Enterprises	Collective Enterprises	Shareholding Enterprises	
Total	14.91	19.01	6.94	54.67	18.36	3.95	21.95	**63.59**
Agri-food Processing	30.94	14.85	12.28	35.49	13.13	3.56	37.21	45.15
Food	15.06	11.25	9.65	58.14	8.63	3.49	19.48	**69.13**
Beverage[3]	17.01	17.09	2.29	**61.28**	25.63	1.34	21.31	**71.03**
Tobacco[2]	113.58	0.21	0.00	9.36	**99.83**	0.00	0.94	0.00
Textile	15.13	14.05	10.88	57.78	8.21	5.12	13.26	**71.29**
Garments	2.14	33.06	0.00	57.73	0.92	8.77	15.69	**62.13**
Leather	3.11	18.64	0.45	**72.82**	1.51	6.04	7.75	**77.54**
Wood Processing[2]	28.07	**80.08**	0.00	**68.02**	3.01	14.50	36.40	36.47
Furniture	5.56	41.38	0.00	46.52	0.92	4.06	13.63	**65.76**
Paper[3]	11.36	26.50	0.25	51.08	13.29	9.75	22.66	58.15
Printing	21.66	18.97	0.77	48.09	8.35	4.59	9.27	**60.31**
Educational and Sports Products	3.62	32.95	5.01	57.71	2.53	8.77	20.47	**76.45**
Petroleum Products	**85.77**	1.54	3.72	9.86	**78.23**	1.01	**81.50**	11.87
Chemical Products[3]	17.10	13.72	6.37	59.62	18.20	3.17	19.51	**61.66**
Pharmaceutical Products[3]	37.24	11.16	4.05	44.35	34.86	5.03	36.80	43.85
Chemical Fiber[3]	7.07	13.80	38.44	32.26	21.46	1.99	17.10	**67.92**
Rubber[2, 3]	47.30	41.26	0.00	230.86	19.92	5.68	17.93	**63.73**
Plastics	5.63	31.95	5.88	52.04	4.21	5.44	15.55	**71.26**
Nonmetal Mineral Products	18.05	36.23	7.27	32.25	6.99	13.73	33.02	34.66
Ferrous Metals Smelting[2 3]	36.83	23.79	38.48	14.85	43.56	4.38	38.89	45.20
Nonferrous Metals Smelting	41.18	23.91	1.43	26.38	14.99	11.75	42.68	34.82
Metal Products	6.01	28.99	1.97	57.58	2.63	6.12	17.24	**60.06**
General Mechanical Products[3]	35.54	20.88	2.64	36.22	20.77	6.26	24.57	53.94
Special Mechanical Products	27.15	27.50	4.88	32.15	7.86	4.48	23.58	55.60
Transportation Equipment[3]	16.87	15.57	9.70	49.29	45.07	1.91	11.72	**78.93**
Electrical Equipment	9.42	21.69	19.08	43.47	4.91	3.60	34.18	50.31
Telecommunication and Computer[3]	0.79	7.58	1.93	**79.85**	17.60	0.40	18.54	**79.04**
Instruments and Office Machinery	7.47	7.09	0.57	**83.02**	1.32	2.08	3.39	**92.80**

Source: Various issues of the *Guangdong Statistical Yearbook*.
Notes: 1. Share values over 60 percent are marked in bold text.
2. The sum of the ratios of industrial gross output value of four categories in 1997 surpasses 100 percent. Double counting might exist in the data collection process.
3. The sum of the ratios of industrial gross output value of ten categories in 2003 surpasses 100 percent. Double counting might exist in the data collection process.

Table 6.3: Labor Productivity of State-owned, Collective, Shareholding, and Foreign Enterprises in Guangdong province (10^4 RMB/Person): 1997 and 2003

Sectors	1997				2003			
	Domestic Enterprise			Foreign Enterprises	Domestic Enterprise			Foreign Enterprises
	State-Owned Enterprises	Collective Enterprises	Shareholding Enterprises		State-Owned Enterprises	Collective Enterprises	Shareholding Enterprises	
Agri-food Processing	2.23	4.66	4.85	14.32	7.30	10.07	9.57	14.63
Food	2.16	1.84	4.39	7.45	5.18	4.80	6.28	12.98
Beverage	**3.88**	**3.74**	**4.06**	**13.03**	**27.77**	**5.14**	**17.36**	**23.40**
Tobacco	30.90	1.40	N.A.	24.15	80.04	N.A.	4.79	N.A.
Textile	1.21	1.70	5.70	3.18	4.17	3.61	4.25	5.30
Garments	**1.50**	**1.32**	**N.A.**	**1.84**	**1.88**	**3.01**	**3.92**	**2.40**
Leather	**0.92**	**1.45**	**0.35**	**0.45**	**2.54**	**2.59**	**3.13**	**1.84**
Wood Processing	**3.29**	**2.79**	**N.A.**	**4.41**	**5.16**	**8.20**	**7.61**	**4.45**
Furniture	**1.39**	**1.78**	**N.A.**	**2.04**	**2.73**	**3.05**	**4.68**	**3.47**
Paper	**2.19**	**2.57**	**3.20**	**5.85**	**11.41**	**6.78**	**6.42**	**10.21**
Printing	**2.18**	**2.46**	**1.41**	**3.40**	**5.78**	**5.46**	**7.42**	**4.90**
Educational and Sports Products	**2.46**	**1.32**	**1.48**	**1.32**	**9.49**	**1.43**	**4.36**	**2.02**
Petroleum Products	8.62	6.57	22.23	36.78	55.84	4.58	60.77	77.62
Chemical Products	1.72	2.84	4.05	12.72	11.23	7.41	10.47	31.74
Pharmaceutical Products	**4.58**	**3.49**	**2.98**	**13.85**	**12.90**	**7.88**	**11.78**	**12.59**
Chemical Fiber	**1.15**	**2.74**	**6.06**	**2.35**	**8.73**	**11.97**	**4.42**	**11.09**
Rubber	**1.39**	**2.10**	**N.A.**	**2.56**	**6.52**	**3.36**	**11.47**	**3.80**
Plastics	**3.64**	**2.39**	**10.01**	**3.24**	**5.93**	**5.56**	**6.56**	**5.11**
Nonmetal Mineral Products	1.35	1.62	2.35	3.62	5.08	4.09	5.81	7.36
Ferrous Metals Smelting	1.91	4.09	5.33	7.50	18.92	9.38	12.87	31.80
Nonferrous Metals Smelting	2.32	3.64	1.10	7.10	9.51	10.67	11.05	20.47
Metal Products	2.09	2.17	3.36	4.50	4.60	4.66	4.84	6.32
General Mechanical Products	1.65	1.97	1.71	5.67	8.04	5.87	5.29	10.64
Special Mechanical Products	**1.46**	**2.30**	**5.30**	**4.94**	**4.47**	**5.57**	**6.69**	**6.06**
Transportation Equipment	**2.11**	**2.13**	**7.67**	**9.27**	**25.40**	**3.76**	**7.48**	**22.83**
Electrical Equipment	**2.79**	**2.99**	**30.27**	**2.88**	**8.62**	**3.41**	**12.27**	**5.78**
Telecommunication and Computer	**2.98**	**2.49**	**1.96**	**6.58**	**37.30**	**0.95**	**35.60**	**11.82**
Instruments and Office Machinery	2.39	1.45	0.34	3.85	6.50	1.22	6.67	10.26

Table 6.4: Average Annual TFP Growth Rate of State-owned, Collective, Shareholding, and Foreign Enterprises in Guangdong province (Percentage), 1997-2003

Sectors	State-Owned Enterprises	Collective Enterprises	Shareholding Enterprises	Foreign Enterprises
Agri-food Processing	**13.22**	-1.53	**8.31**	5.88
Food	8.29	**13.05**	9.08	9.78
Beverage	**16.60**	4.45	**28.04**	9.87
Tobacco[1]	12.19	-8.69	-9.55	-37.91
Textile	**12.78**	**11.98**	1.43	9.07
Garments	6.10	**13.52**	**11.10**	6.73
Leather	20.50	12.82	**42.49**	21.23
Wood Processing	-9.29	4.54	**43.33**	6.11
Furniture	8.32	**13.55**	**17.54**	11.34
Paper	**10.26**	**7.47**	**13.13**	4.06
Printing	**7.68**	**6.14**	**21.21**	5.59
Educational and Sports Products	**11.14**	5.40	**11.22**	6.99
Petroleum Products	9.53	-9.80	1.34	13.11
Chemical Products	**15.47**	**11.86**	**11.21**	10.69
Pharmaceutical Products	**12.61**	**4.20**	**17.58**	3.11
Chemical Fiber	13.08	**38.87**	15.73	23.79
Rubber	**10.15**	6.20	1.74	9.05
Plastics	1.23	**14.37**	1.82	10.59
Nonmetal Mineral Products	**19.20**	10.82	**17.42**	15.78
Ferrous Metals Smelting	**17.93**	**19.19**	7.81	9.00
Nonferrous Metals Smelting	12.56	**21.25**	**47.52**	15.57
Metal Products	4.46	**13.17**	8.05	11.70
General Mechanical Products	**18.31**	**18.63**	9.76	14.02
Special Mechanical Products	**11.05**	**5.41**	**4.34**	1.97
Transportation Equipment	**29.59**	9.21	**16.43**	14.95
Electrical Equipment	12.10	6.05	1.19	14.79
Telecommunication and Computer	**38.05**	-11.54	**34.58**	8.47
Instruments and Office Machinery	13.18	5.43	**35.80**	18.26

Note: 1. State-owned firms held the dominant share in the tobacco sector during the observation period due to China's state tobacco monopoly policy. Thus the negative TFP growth rates of collective, shareholding, and foreign companies should be interpreted with caution.

As Blomstrom and Kokko (1998, 2001) suggest, developing countries seek to attract FDI primarily to acquire technology, knowledge, and managerial skills that is transferred from advanced investors. Through FDI, which inevitably brings competition, labor mobility, the demonstration effect of foreign firm activity, forward or backward linkages between foreign and domestic firms, etc., laggard domestic players can acquire know-how in areas such as advanced production technology and processes, products and marketing, and sales and management. Theoretically, if domestic firms were to succeed in mastering such advanced production technologies and managerial knowledge, they would achieve swifter productivity growth, which is considered a spillover from FDI. The empirical models—notwithstanding whether the search for the FDI contribution to domestic productivity gains is based on sectoral level data such as in Caves (1974) or Blomstrom (1986) or on firm-level data exemplified by Aitken and Harrison (1999), Javorcik (2004), or Marin and Bell (2006)—can be summarized as follows:

(8) Domestic Firm Productivity Growth = Foreign Investment Presence + Control Variables + Residual

In line with this empirical analytical framework, we test the hypothesis that improvement in the productivity of domestic manufacturing firms in Guangdong is attributable to the foreign investment in the province, principally from Hong Kong. For the dependent variable, we use the panel of TFP annual growth rates of the 28 manufacturing sectors and four ownership groups as attained in section 6.2. As data for Hong Kong FDI in Guangdong's manufacturing sectors are not available, we use the next best available data, that is, the registered capital from HKMT over the period 1999 to 2003. According to various issues of the Guangdong Statistical Yearbook, FDI from Hong Kong accounted for about 90 percent of HKMT capital in the period of 1988-2003. As this percentage varied only minimally during our observation period, i.e. between 1999 and 2003 (Figure 6.1), HKMT registered capital divided by total registered capital serves as a reliable proxy for the Hong Kong capital presence in

Guangdong manufacturing sectors.[32] Similarly, non-HKMT foreign capital divided by total registered capital also enters the regression as the independent variable, representing the presence of foreign capital other than what comes in from HKMT.

The regression is controlled by the R&D expenditure/output ratio, the new product output share, and the export volume-output value ratio. Including R&D intensity as a control variable is justified by the causal relationship between R&D and productivity enhancement, as confirmed by various studies such as Griliches (1980, 1994). According to von Tunzelmann and Acha (2005), high-tech industries whose R&D intensities are greater than 5 percent account for only around 3 percent of added-value in OECD countries. Adding medium-to-high-tech industries merely increases the proportion to 8.5 percent, which means the majority of industries in developed countries are characterized by low ratios of R&D intensities. It is thus expected that even lower ratios of R&D intensity would be found in Guangdong manufacturing sectors. Importantly, R&D alone does not represent all the innovation efforts and activities of manufacturing firms; design, engineering development and experimentation, adoption-related learning activities, and exploration of markets for new products are also important contributors to innovation efforts (Smith, 2005). We therefore regard the new product output share as a control variable to take account of the broadly defined innovation efforts undertaken by Guangdong manufacturing firms. The designation 'new product' in Guangdong industrial statistics denotes a product that is new to manufacturing firms in the reporting period, 1999-2003.

The World Bank's 1993 study indicates that, during the catching-up period, exporters in developing countries may have benefited from the technical expertise of their

[32] There are no data exactly specifying the percentage of HKMT FDI invested in manufacturing that is from Hong Kong. Through Figure 1, however, we know that about 90 percent of HKMT FDI invested in all sectors is from Hong Kong, with 70 percent of FDI invested in Guangdong going to manufacturing sectors. We could thus estimate the ratio of Hong Kong FDI in total HKMT FDI invested in manufacturing sectors. If Hong Kong and Macau and Taiwan invest proportionately in manufacturing, which means HK, Macau and Taiwan each invest their 70 percent FDI in manufacturing, HK FDI would account for 90 percent of HKMT FDI in manufacturing sectors, as in all sectors. Let us assume an extreme case in which Hong Kong invests disproportionately less in manufacturing sectors, and Macau and Taiwan invest disproportionately more in manufacturing sectors. For instance, suppose that 40 percent of Hong Kong FDI goes to manufacturing while 60 percent is invested in the other sectors. Suppose that 90 percent of Macau and Taiwan FDI goes to manufacturing and 10 percent to the other sectors. Then, in manufacturing sectors, the ratio of Hong Kong FDI to HKMT FDI would still be 80 percent. As we indicate in the section 1, evidence abounds that HK invests heavily in manufacturing sectors in Guangdong, so 40 percent is an impossibly low percentage and the case is extreme.

sophisticated buyers in developed nations. Although there are few econometric analyses claiming to find even modest learning-by-exporting effects, the anecdotal case studies of manufacturing firms in East Asian countries emphasize that firms benefit from interaction with foreign customers (Keller, 2004). Due to the similarity of Guangdong's industrial development path to that of East Asian countries generally—characterized by an export-orientation policy and export volume expansion—we include the export volume-output value ratio among the control variables in the regression.

We use the fixed-effect panel data model to estimate the regression function since it controls the heterogeneity associated with our industrial sector-level data better than OLS regression. The Hausman Test is performed to test whether the assumption of random effect model is valid. Because the impact of contributing factors could take years to occur, we construct one-year lag and two-year lag independent variables to measure the effect of past-period FDI on current-period productivity growth. Two years is the longest lag we can test in the regression without significantly losing the observations. The available two-digit sector-level R&D expenditure data, which is divided into three ownership groups, date back only to 2001. The remaining data are available from 1999 onwards. We therefore form a panel including the data on 28 two-digit manufacturing sectors and three ownership groups over the period 2001-2003. The data are taken from various issues of the Guangdong Statistical Yearbook and the Guangdong Industrial Statistical Yearbook.

The estimation result presented in Table 6.5 reveals that the coefficient of the HKMT capital presence is either insignificantly positive or significantly negative, which provides no evidence that HKMT investment boosts domestic productivity gains. Moreover, we find no statistically significant effects of non-HKMT foreign capital. Contrary to the absence of positive influence of foreign investors' equity participation on domestic firms, however, the impact of control variables is distinct. The coefficients of new product output share, export volume-output ratio, and R&D intensity are significantly positive in two of the three regressions. Given the small number of observations, anomalous results are not surprising; the result demonstrates that innovation efforts and a learning-by-exporting effect contributed, to a certain extent, to TFP growth in Guangdong domestic manufacturing firms over our observation period, 1999-2003.

It is important to bear in mind that most foreign capital in Guangdong manufacturing sectors is concentrated in foreign rather than domestic firms. As Table 6.2 shows, foreign firms accounted for more than 60 percent of industrial gross output in 17 out of 28 manufacturing sectors in Guangdong in 2003. To ascertain the possible influence of overall foreign capital in Guangdong manufacturing sectors, we first regress the TFP growth of state-owned firms on the ratio of HKMT and non-HKMT foreign capital to total state-owned firms' registered capital. The ratios of HKMT capital and non-HKMT foreign capital to total registered capital in all Guangdong manufacturing sectors also enters the regression as the proxy for foreign capital presence in all manufacturing firms in Guangdong. A similar regression is run on collective and shareholding firms. The result of the random effect is reported in addition to that of the fixed-effect model, since the assumption of random effect is not rejected. None of the coefficients of the overall HKMT capital-total registered capital ratio or the overall non-HKMT foreign capital-total registered capital ratio is significant (Table 6.6). One-year lag and two-year lag regressions are implemented, but they do not generate significant coefficients.[33] These findings imply that foreign firm activity does not in general exert a material influence on productivity gains in domestic firms.

This result, based on available data, is limited in scope because the data that are utilized come only from a recent period of time (earlier data is unavailable from official sources) and there were relatively few observations, so we face difficulties in examining the potential endogenous relationship between the control and dependent variables and in testing the long time lag of the impact of the control variables. The sector-level data are the best data available with which to analyze Guangdong's manufacturing sectors. Significantly, however, the absence of any positive impact from HKMT capital and non-HKMT capital on the observed rapid productivity growth in Guangdong domestic firms is consistent, no matter which forms of regression we examine and how many years of lag we test in the regressions.

[33] The regression results are available from the authors upon request.

Table 6.5: Regression of TFP Growth of Guangdong Domestic Manufacturing Firms on Several Potential Explanatory Factors: Fixed-Effect Model[1]

Independent Variables	Coefficient (Standard Deviation)		
	TFP Growth of Guangdong Domestic Manufacturing Sectors (2000-2001, 2001-2002, 2002-2003)		
	No Lag – Independent Variables Period: 2001,2002,2003	One-Year Lag – Independent Variables Period: 2000, 2001,2002	Two-Year Lag – Independent Variables Period: 1999, 2000,2001
HKMT Capital/Total Registered Capital	.023 (.316)	-.483 (.285)*	-.973 (.306)***
Non-HKMT Foreign Capital/Total Registered Capital	-.394 (.351)	.190 (.311)	-.034 (.346)
New Product Output Value/Gross Industrial Output Value	.614 (.360)*	.416 (.369)	.634 (.362)*
Export Volume/Gross Industrial Output Value	.165 (.228)	.554 (.226)**	.433 (.229)*
R&D Expenditure/Gross Industrial Output Value[1]	8.24 (4.96)*	10.9 (4.98)**	7.21 (4.74)
Number of Observations	249	249	249
Number of Groups	28	28	28
F-Statistics	2.23*	3.02**	3.83***
Hausman Test Chi-square	6.21	12.08**	10.05*

Notes: 1. *** denotes significance at the 1% level; ** denotes significance at the 5% level; * denotes significance at the 10% level.
2. The data for R&D Expenditure are available only for 2001, 2002 and 2003. We thus have no way to construct the one-year lag and two-years lag variables for R&D Expenditure/Gross Industrial Output Value. The no-lag variable, which is for the period of 2001-2003, enters the one-year lag and two-year lag regressions.

Table 6.6: Regression of TFP Growth in Guangdong Domestic Manufacturing Sectors on Foreign Capital Presence: 1999-2003[1]

Independent Variable	Coefficient (Standard Deviation) Dependent Variable: TFP Growth of State-Owned Enterprises		TFP Growth of Collective Enterprises		TFP Growth of Shareholding Enterprises	
	Fixed Effect	Random Effect	Fixed Effect	Random Effect	Fixed Effect	Random Effect
HKMT Capital/Total Registered Capital in the Enterprises of Specific Ownership Form (State-Owned or Collective or Shareholding)	.597 (.559)	.336 (.351)	-.570 (.555)	-.712 (.346)**	-.692 (.479)	-.027 (.341)
Non-HKMT Foreign Capital/Total Registered Capital in the Enterprises of Specific Ownership Form (State-Owned or Collective or Shareholding)	.240 (.679)	.357 (.427)	-1.514 (.588)**	-.497 (.358)	.653 (.613)	.804 (.510)
Ratio of HKMT Capital to Total Registered Capital in All Enterprises	-.618 (.736)	-.100 (.176)	.806 (.651)	.306 (.196)	-.034 (.711)	-.054 (.173)
Ratio of Non-HKMT Foreign Capital to Total Registered Capital in All Enterprises	-.807 (.884)	-.172 (.311)	.888 (.782)	.114 (.294)	.276 (.831)	.144 (.291)
Number of Observations	139		138		140	
Number of Groups	28		28		28	
Hausman Test Chi-square	1.37		7.19		3.97	

Note: 1. *** denotes significance at the 1% level; ** denotes significance at the 5% level; * denotes significance at the 10% level.

6.4 Recent Policy Developments in Hong Kong and Guangdong

6.4.1 Discussion of Results

The first explanation we posit to reconcile the above-mentioned paradox—that foreign firms' introduction to and expansion in Guangdong's manufacturing sectors brought minimal gains in productivity—is that domestic manufacturing firms in Guangdong are more committed to using R&D to enhance productivity than their foreign counterparts. Table 6.7 shows that in almost all sectors, the average R&D intensities (R&D expenditure divided by production value) of at least one ownership group of domestic firms are higher than or equal to those of foreign firms. In 2000, seven ministries in the Chinese central government jointly launched the first national R&D census. The published data support our hypothesis about Guangdong's manufacturing sectors. As shown in Table 6.8, HKMT-invested enterprises placed themselves in an unfavorable position against their domestic counterparts in terms of R&D and innovation, despite controlling a considerable portion of manufacturing production in Guangdong province.

The second reason we propose to account for the lower productivity growth of foreign manufacturing firms in Guangdong—which are dominated by those from Hong Kong—lies in a critical reflection on the historical transition of firms in Hong Kong's manufacturing industry and the changing nature of cross-border production in Guangdong and Hong Kong. From its early beginnings (between the 1950s and 1970s) technological sophistication had little to do with the establishment of Hong Kong manufacturing firms in both Hong Kong and Guangdong. In fact, the roots of Hong Kong manufacturing can be traced to the opportunistic exploitation of a geographic area by Mainland Chinese immigrants, particularly textile barons from Shanghai (fleeing the communist regime), who transferred start-up capital and managerial expertise to the territory (Wong, 1988; Hollows, 1999).[34] Over time, however, as Hong Kong manufacturers faced limits on low-cost manufacturing, they found an escape route for their manufacturing industries in the shape of the opening-up of China from 1979 onwards (leading to cheaper land and labor resource costs). Unlike the driving forces of

[34] These Shanghai industrialists concentrated on low-cost manufacturing in the labor-intensive textile and clothing industries and turned to the British trading houses in Hong Kong, which had established links with international export markets (Tsui-Auch, 1998: 9).

other newly industrialized East Asian economies, Hong Kong's entrepreneurs, because of their linguistic and cultural familiarity, could easily leverage the abundant labor and land resources in Guangdong to offset the disadvantage of heightened labor costs. Enjoying the cost advantage of cross-border production in Guangdong, Hong Kong's manufacturing firms did not pursue technological sophistication nearly as vigorously as did their counterparts in the other 'Asian tigers.' Among Hong Kong-owned firms, automated processes were limited, and R&D activities were few (Eng, 1997).[35] Indeed, in the early 1980s, Hong Kong was not recognized as a major source of advanced technology by firms in China and the technology transferred through Hong Kong's FDI outflows was either low-level or standardized technology (Kamath, 1990).

6.4.2 The Recent Policy Reaction in Hong Kong and Guangdong

Partly as a result of their acknowledgment that Hong Kong-based firms do not achieve productivity growth through investments in R&D, and partly as a result of Guangdong's intense efforts to move up the value-added ladder, Hong Kong policymakers began to reconsider their future engine for economic growth in light of the marginalized role of manufacturing in the territory, its decreasing importance as a trading hub, and the scarcity of opportunities for further reducing factor input costs. A 'Commission on Innovation and Technology' (CIT) based its vision of Hong Kong's new role explicitly on science, technology, and innovation (HKSAR, 1999). Since the publication of the Commission's two reports (HKSAR, 1998, 1999), Hong Kong has launched several measures to increase competitiveness through methods other than lowering factor input costs. Most notable among these measures was the establishment of the 'Innovation and

[35] The idea that the growth and profitability of Hong Kong's manufacturing firms was based on lowering their factor input costs is supported by many scholars in the field. For example, Kwong et al. (2000) find that, during the period of 1984-1993, firms in Hong Kong's manufacturing sector demonstrated an overall decrease in TFP, although such a technological decline did not mean lower profitability. It was during this period that Hong Kong firms engaged in a frenzy of manufacturing facility relocation to Guangdong. Because the unfinished products shipped at low prices from the manufacturing base in Guangdong, firms in Hong Kong could enjoy high profitability even as productivity declined. Thus Kwong et al. conclude that Hong Kong has grown mainly by utilizing China's cheaper resources, instead of through technological advancement. They also argue that technology upgrading might have seemed too daunting a task for firms in Hong Kong as compared with moving the production base to Guangdong to maintain a competitive edge in global markets. Tuan and Ng's (1995) findings complement those of Kwong et al. Tuan and Ng find that the principal reasons that Hong Kong firms moved their manufacturing base to Guangdong were Guangdong's cheap labor costs, low rents, and geographical proximity. A higher return on investment, a shorter pay-back period, and factor-cost savings are strongly associated with the cross-border operation of Hong Kong manufacturing firms. Therefore, existing studies already provide historical and empirical evidence that helps explain our findings related to productivity growth in Guangdong manufacturing sectors and the potential impact of Hong Kong-based firms.

Technology Fund' (ITF) in 1999 with 640 million US Dollars, earmarked to provide funding support to projects that contribute to innovation and technology upgrading in industry, as well as to projects essential to the upgrading and development of new industries.[36,37] The main purpose of the ITF was to counter what scholars such as Kwong et al. (2000) and Tuan and Ng (1995) were advocating: increasing competitiveness through higher value-added goods and services. Furthermore, in June 2004, the government proposed a new strategic framework for innovation and technology development. A main element in this framework is to 'leverage the Mainland,' that is, to utilize the production base in the Guangdong region as a platform for developing applied R&D and the commercialization of applied R&D deliverables. This proposal reflected the increasing interest of Hong Kong-based firms in conducting R&D in Guangdong. Lastly, in 2004, the ITF also instituted, in parallel with the above-mentioned initiative, a funding scheme for Hong Kong-Guangdong technology cooperation. In this scheme, a total of 44 million US Dollars is made available to fund 86 chosen projects, thereby enhancing technology cooperation and raising the value-added on goods and services produced in Hong Kong and Guangdong. Each partner receives 22 million US Dollars from this scheme.

Recognizing the importance of investments in R&D, and to strengthen its support of indigenous R&D and innovation efforts, China's central government announced an ambitious strategy (in March 2006) for nurturing 'home-grown' innovation over the next decade.[38] Half a year earlier, in September 2005, the Guangdong provincial government published its own "Decision on Enhancing Indigenous Innovation Capability and Improving Industry Competitiveness" (Guangdong Provincial Government, 2005). The earlier announcement of Guangdong's version of its indigenous innovation strategy demonstrates its ambition to strengthen its role as an

[36] The exchange rate of US Dollar: HK Dollar is 1:7.8 as of April 2006.

[37] Before the ITF was set up, there were two other funds in place providing financial assistance to projects that would enhance the competitiveness of local industry. One was the Industrial Support Fund (ISF) established in 1994 (subsumed by the Innovation and Technology Fund in June 1999), and the second was the Services Support Fund established in 1996 (subsumed by the Innovation and Technology Fund in June 1999).

[38] The concrete goals set in the blueprint for 2006-2020 include bringing the ratio of gross expenditure on R&D to GDP to 2.5 percent in 2020, seeing technological progress contribute 60 percent of economic growth, growing business expenditures in R&D to twice as much as expenditures on technology transfer (as the degree of dependence on foreign technology is reduced below the level of 30 percent), and increasing the number of invention patents granted to Chinese citizens and the citation of international scientific papers so that both will rank among the top five in the world (State Council, 2006).

engine for economic growth in the Southern China region, as well as for maintaining the competitive edge of its industries in the increasingly competitive global marketplace. The "Decision" calls for strengthening Guangdong's innovation system, reducing Guangdong's dependence on foreign technology, fostering the central role of enterprises in the innovation system, strengthening the industry-academy relationship, protecting intellectual property rights, and promoting international cooperation.[39]

Guangdong province's innovation initiatives mirror Hong Kong's actions in promoting innovation, creating further opportunities for cooperation between Guangdong and Hong Kong. If Guangdong's goals are successfully fulfilled, the province is set to play a more important role in economic integration and regional development in the Pearl River Delta region, which includes Hong Kong and Macau. The expectation is that, because of its low factor-input costs, more foreign firms will want to conduct R&D in Guangdong in addition to merely locating their manufacturing plants there.

The rise of Guangdong as an innovation center in the region could pose a serious challenge to Hong Kong's ambition to act as an R&D hub, as both foreign and Hong Kong-based firms would have the choice of Guangdong as a potential alternative site at which to set up their R&D activities. Since Hong Kong and Guangdong are becoming ever more closely integrated, our findings suggest that mutual economic interdependence calls for the delicate coordination of industrial and innovation policy, such that the interests of both regions are promoted hand-in-hand.

[39] Quantitative targets for the execution are specified in the document. For instance, granted invention patents per million inhabitants will reach 80 by 2010, the high-tech sector's added value will account for 35 percent of the total added value of all industries, and the share of new product sales in total product sales will grow to 20 percent.

Table 6.7: Average R&D Intensities of State-owned, Collective, Shareholding, and Foreign Enterprises in Guangdong Province (Percentage), 2001-2003

Sectors	State-Owned Enterprises	Collective Enterprises	Shareholding Enterprises	Foreign Enterprises
Agri-food Processing	**0.06**	**0.08**	**0.05**	0.03
Food	**0.12**	**0.20**	**0.33**	0.08
Beverage	**0.19**	**0.46**	**0.28**	0.04
Tobacco	0.04	N.A.	N.A.	N.A.
Textile	**0.03**	0.02	**0.03**	0.03
Garments	**0.04**	**0.06**	**0.17**	0.02
Leather	0.00	**0.07**	0.02	0.04
Wood Processing	0.01	0.01	**0.66**	0.04
Furniture	0.01	**0.05**	**0.06**	0.04
Paper	**0.11**	0.02	0.04	0.11
Printing	**0.05**	**0.08**	**0.09**	0.04
Educational and Sports Products	**0.20**	**0.08**	**0.09**	0.04
Petroleum Products	**0.07**	**0.04**	**0.05**	0.00
Chemical Products	0.16	0.06	**0.22**	0.17
Pharmaceutical Products	**0.93**	0.14	**1.18**	0.71
Chemical Fiber	**0.05**	0.00	0.00	0.02
Rubber	**0.15**	**0.08**	**0.13**	0.05
Plastics	0.07	0.02	0.07	0.08
Nonmetal Mineral Products	**0.24**	**0.11**	**0.13**	0.09
Ferrous Metals Smelting	0.11	0.02	0.02	0.15
Nonferrous Metals Smelting	**0.34**	0.02	**0.17**	0.05
Metal Products	**0.30**	**0.05**	**0.05**	0.05
General Mechanical Products	**0.46**	**0.23**	**0.34**	0.21
Special Mechanical Products	**1.22**	0.38	**0.90**	0.58
Transportation Equipment	**0.21**	0.11	0.13	0.21
Electrical Equipment	**0.26**	0.15	**0.88**	0.21
Telecommunication and Computer	**1.68**	**0.42**	**5.19**	0.24
Instruments and Office Machinery	**1.54**	0.04	**1.23**	0.23

Source: Various issues of *Guangdong Industrial Statistics Yearbook*.

Table 6.8: Several Innovation Indicators of State-owned, Collective, Shareholding, and Hong Kong/Macau/Taiwan-Invested and Foreign Enterprises in Guangdong: 2000 Data

Indicator	Domestic Enterprises			Foreign Enterprises	
	State-owned Enterprises	Collective Enterprises	Shareholding Enterprises	Hong Kong/Macau/Taiwan-Invested Enterprises	Other Foreign Enterprises
Added Value as a share of Total (Percentage)	17.84	9.36	14.90	40.05	17.86
Labor Productivity (Thousand RMB/Person)	88.64	33.00	81.23	52.82	83.35
R&D Intramural Expenditure/Added Value (Percentage)	2.62	0.78	2.84	1.37	1.34
R&D Personnel Full Time Equivalent/Annual Average Number of Employed Personnel (Percentage)	0.91	0.24	0.35	0.29	0.57
New Product Output/Total Output (Percentage)	9.60	1.89	11.31	7.76	10.60
Patent Application/Value Added (Unit per Million RMB)	70.12	152.58	143.96	88.26	77.52
Invention Patent Application/Added Value (Unit per Million RMB)	37.06	36.15	23.33	19.61	15.99
Technology Upgrading Expenditure/Added Value (Percentage)[1]	4.61	0.93	2.97	1.53	2.60

Source: *National Industrial Statistics on the 2000 R&D Census* and *Guangdong Statistical Yearbook, 2001*.

Note: 1. Technology upgrading expenditure specified in the National Industrial Statistics on the 2000 R&D Census includes expenditure of purchasing technology from domestic and foreign sources, training personnel, tax deductions from various levels of government for in-house R&D activity, and other expenditures related to the technology upgrading.

Table 6.9: Harmonization of Manufacturing Sector Categorization

Abbreviation in this Paper	Categorization in Guangdong Statistical Yearbook	Categorization in ISIC Rev 3.1[1]	
		Code	Sector Name
Agri-food Processing Food Beverage	Farm and Sideline Food Processing Food Manufacturing Beverage Manufacturing	D15	Manufacture of Food Products and Beverages
Tobacco	Tobacco Products	D16	Manufacture of tobacco products
Textile	Textile Industry	D17	Manufacture of textiles
Garments	Textile Garments, Footwear and Headgear Manufacturing	D18	Manufacture of wearing apparel; dressing and dyeing of fur
Leather	Leather, Furs, Down, and Related Products	D19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery harnesses, and footwear
Wood Processing	Timer Processing, Bamboo, Cane, Palm Fiber, and Straw Products	D20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
Furniture	Furniture Manufacturing	D36	Manufacture of furniture; manufacturing n.e.c.
Paper	Papermaking and Paper Products	D21	Manufacture of paper and paper products
Printing	Printing and Record Medium Reproduction	D22	Publishing, printing, and reproduction of recorded media
Educational and Sports Products	Culture, Educational, and Sports Goods	D36	Manufacture of furniture; manufacturing n.e.c.
Petroleum Products	Petroleum Refining, Coking, and Nuclear Fuel Processing	D23	Manufacture of coke, refined petroleum products, and nuclear fuel
Chemical Products Pharmaceutical Products Chemical Fiber	Raw Chemical Materials and Chemical Products Medical and Pharmaceutical Products Chemical Fiber	D24	Manufacture of chemicals and chemical products
Rubber Plastics	Rubber Products Plastic Products	D25	Manufacture of rubber and plastics products
Nonmetal Mineral Products	Nonmetal Mineral Products	D26	Manufacture of other non-metallic mineral products
Ferrous Metals Smelting Nonferrous Metals Smelting	Smelting and Pressing of Ferrous Metals Smelting and Pressing of Nonferrous Metals	D27	Manufacture of basic metals
Metal Products	Metal Products	D28	Manufacture of fabricated metal products, except machinery and equipment
General Mechanical Products Special Mechanical Products	General Purposes Equipment Manufacturing Special Purposes Equipment Manufacturing	D29	Manufacture of machinery and equipment n.e.c.

Table 6.9 (Continued)

Transportation Equipment	Transport Equipment Manufacturing	D34	Manufacture of motor vehicles, trailers, and semi-trailers
		D35	Manufacture of other transport equipment
Electrical Equipment	Electric Equipment and Machinery	D31	Manufacture of electrical machinery and apparatus n.e.c.
Telecommunication and Computer	Telecommunications, Computers, and Other Electronic Equipment Manufacturing	D32	Manufacture of radio, television, and communication equipment and apparatus
Instruments and Office Machinery	Instruments, Meters, Cultural, and Office Machinery	D30	Manufacture of office, accounting, and computing machinery
		D33	Manufacture of medical, precision, and optical instruments, watches, and clocks

Note: 1. *International Standard Industrial Classification of All Economic Activities Revision 3.1* is from Statistics Division, United Nations. Available from:
http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=17.
(accessed 24 August 2005).

Table 6.10: Formation of Variables for TFP Calculation[1]

Variables Entered in the Function (1)	Variables Directly or Calculated from the Statistical Yearbook	Deflator or Calculation Equation	Deflator Data Description	
			1997-2000	2001-2003
Deflated Added Value	Industrial Added Value (100 million RMB at current price)	Deflator of Added Value = Ex-factory Price Indices of Industrial Products (2000 Price as 1)	Data cover only 15 industry sectors. The general indices for all sectors are adopted for the industry sectors which lack of data.	Data cover 37 two-digit industry sectors.
Deflated Capital Input	Average Balance of Net Value of Fixed Assets for Production	Average Balance of Net Value of Fixed Assets for Production = (1) Average Balance of Net Value of Fixed Assets * (2) Ratio of Fixed Assets for Production to Total Fixed Assets		
	(1)Average Balance of Net Value of Fixed Assets (100 million RMB at current price)	Deflator of Average Balance of Net Value of Fixed Assets = Price Indices of Investment of Fixed Assets (2000 Price as 1)	Data are available for the period of 1997-2003.	
			1997-2000	2001-2003
	(2) Ratio of Fixed Assets for Production to Total Fixed Assets	Ratio of Fixed Assets for Production to Total Fixed Assets = Fixed Assets for Production[1] (100 million RMB, without depreciation)/Total Fixed Assets[1] (100 million RMB, without depreciation)	Not Available. The mean of the data in the period of 2001-2003 is adopted for this period.	Panel Data cover three ownership groups, i.e. state-owned, collective and foreign enterprises and 37 two-digit industry sectors. The capital deflator of state-owned enterprises is also applied to shareholding enterprises.
Labor Input	Annual Average Number of Employed Persons (10 000 persons)			

Note: 1. All the variables and price deflators are taken from various issues of the Guangdong Statistical Yearbook except for Fixed Assets for Production and Total Fixed Assets, which are taken from various issues of China Industry Economy Statistical Yearbook.

Chapter 7 Conclusion and Policy Implications

This thesis studies the Chinese innovation system and innovation policy. It also focuses on the technological catching-up and competitiveness of Chinese firms which are in the center of the national innovation system.

Chapter 2 of the thesis analyzes China's economic transformation and gradual integration into global economy in the past two decades, which delineates the backdrop for the research of China's innovation policy making and the dynamics of manufacturing firms conducted in the rest chapters of the thesis. Chapter 3 provides a comprehensive description of China's innovation policy framework and analyzes the drawbacks of those policies by comparing with the practices in the EU and OECD countries. Extending the works of International Development Research Center (1997), Gu (1999) and Lu (2000), it lays out an analysis framework combining different innovation policy actions at China's national level and highlights the mutual support among them. It investigates the different policies that play important roles in China's innovation system, including reform in the public S&T institutions, financial policy, business innovation support structure, human resource policy and legislative actions. A detailed analysis of the education and human resource policy and the intellectual property right policy is conducted.

The reform of China's centrally-planned S&T system which began in 1985 constitutes a vital part of the transformation of the country's innovation system. The objective of the reform was to transform the rigid, segmented and inefficient plan-oriented S&T system into a highly dynamic, interactive and efficient system such as those in the leading industrialized countries. To evaluate the policy performance during the reform period, we measure the scientific productivity of China's S&T institutes through adopting the econometric methodology elaborated in Adams and Griliches (1996a, 1996b) and Crespi and Geuna (2004) in Chapter 4. The result reveals that in China's S&T institutes, the full effect of the R&D investment on international publication takes 7 years to occur, and its total effect on patent application lasts 5 years. A 1 percent increase of the R&D investment in China's S&T institutes leads to 0.8 percent growth of China's international papers and 2 percent growth of China's patent application. The most important finding derived from this econometric analysis is that the scientific productivity growth rate of China's S&T institutes has been negative since the 1990s. The result based on the aggregate data at country level shows the average annual growth rate of scientific productivity is -2.9 percent when the output is measured by the publication data, and is -9.5 percent when the output is measured by the patent data.

Firms are in the center of a country's innovation system. The export competitiveness and innovation performance of the firms, to a great extent, are associated with the effectiveness and efficiency of the innovation policy in the country. To deepen the analysis of the Chinese innovation system, Chapter 5 of this study researches the reason for the recent surge of the manufacturing exports from China and Chapter 6 examines the technological catching-up of the manufacturing firms in Guangdong province. In Chapter 5, the data from more than 95,000 Chinese manufacturing firms show no evidence that either unit labor cost or R&D investment, even in high-tech sectors, determines the success of Chinese firms in the foreign market. Although foreign enterprises dominate high-tech exports in China, domestic firms are more committed to R&D than their foreign counterparts. However, the primary reason why Chinese firms have increased exports to foreign markets is their product innovation, connection to foreign capital, and fierce competition. The analysis contributes to the literature consisting of the works by Aggarwal (2002), Zhao and Li (1997), Liu and Shu (2003) and Ozcelik and Taymaz (2004) among others to shed some new lights on why the manufacturing firms in developing countries can be competitive.

In Chapter 6, our analysis on the productivity of Guangdong's locally and foreign-funded manufacturing sectors in the period 1997-2003 disclose that domestic firms have been catching up with their foreign counterparts, including Hong Kong-based firms, even though foreign firms have successfully expanded their output share in Guangdong's manufacturing sectors. We do not find the evidence of a significant positive impact exerted by the economic activity undertaken by foreign firms—both HKMT-funded and non-HKMT-funded firms—on productivity growth in Guangdong's domestic manufacturing sectors. As Hong Kong's FDI accounted for about 90 percent of total HKMT FDI over the period of 1988-2003 in Guangdong, we can safely interpret this to imply that manufacturing activities on the part of Hong Kong firms have not contributed to productivity gains in Guangdong's domestic manufacturing firms (regarding FDI from Hong Kong, Macau and Taiwan, Hong Kong's contribution was by far the greatest). In fact, productivity gains in Guangdong domestic firms result largely from their own commitment to R&D investment and efforts in innovation. In addition to enriching the FDI spillover literature, this research deepens our understanding of the economic relationship between Hong Kong and Guangdong and the manufacturing dynamics resulted from the cross-border production of Hong Kong manufacturing firms.

Although the above conclusions obtained in the previous chapters are derived from the scholarly analyses, we argue they also embrace abundant policy implications which are closely linked to the innovation policy making in China. The policy affects the innovation capability of industrial and academic institutions in a national innovation system, which means that the performance and competitiveness of the firms and research organizations could be enhanced through well-functioned innovation policy. Following this logic, we take scientific findings of this study as a point of departure to discuss the prioritized issues that the future Chinese innovation policy should address.

First of all, education must be set as the priority in central and local governments' budget appropriation and outlays in China. Development in nature is technological improvement and productivity growth. To promote technological change and economic growth, China needs to absorb the advanced foreign technology and also builds up indigenous innovation capability. Both these efforts demand high-caliber human resource. Thus, the formation and improvement of the human capital is critical to China's long-term economic prosperity and social development, which means the performance of the education system would determine the sustainability of economic growth in China.

It is necessary to define a long-term strategy to strengthen the legal and administrative regimes for intellectual property right issues, especially at the local level. The legislation should be more rigorously enforced to curb the infringement of the IPR. Establishing mass education program which aims to foster a culture and social value in favor of protecting IPR should be on the agenda of the policy makers. As the innovation activities of the domestic firms intensify, the domestic innovative enterprises will be self-organized to urge stricter IPR protection. The innovation policy makers should take advantage of this trend to collaborate with the industry and promote the IPR awareness in the society.

Secondly, China's future S&T reform policy needs to emphasize continuous improvement of the funding system, strengthen the internal management of the S&T institutions and fight misconduct activities. The utilization of the growing governmental R&D funding has been recently debated inside China, and even in the international science community.[40] Whether the R&D output has increased proportionally with the recent fast growing R&D input or whether the governmental R&D investment has been best utilized is focus of debate. Our finding may suggest an answer of "no" to the above questions. Given the negative scientific productivity growth rate, it is urgent for the Chinese innovation policy makers to overhaul the current funding mechanism and evaluation system to propose remedy strategies accordingly. If fails to do so, the best R&D proposal will not be financially supported and excellent scientists will lose their motivation to pursue first class research, which can be reflected by negative productivity in the long run.

Thirdly, through examining the export performance of the Chinese manufacturing firms, we uncover that the Chinese exporting firms do not rely on reducing labor cost to succeed in foreign markets. The firms exporting more are those better compensating their employees. These findings contradict the belief that the lifting up the lowest salary would do harm to exporting industry in the coastal industrialized regions and the unemployment there would eventually ensue. We argue what are virtually worrisome are the severe working condition of the under-compensated migrant laborers in some plants in coastal provinces and their exclusion from basic social benefits.

[40] The critical viewpoints of China's recent S&T system's reform were addressed by various scientists in the two series of supplement of *Nature- China Voice I* and *II* in 2003 and 2004. Poo (2004) points out that the reform of the administrative structure and establishment of a merit-based system for staff evaluation and resource allocation is crucial for Chinese S&T institutes' development in the next stage. Wu (2004) and Rao et al. (2004) indicate that the system for evaluating research proposals and distributing funds needs improvement. In Wu's opinion, the research project evaluation in China was limited by very low proportion of the outside reviewers, especially for the big projects. He also argues that China's low-level output is related to the inadequacy and short-term nature of its research funding, which pressed the scientists to produce quick results that lacked novelty. Additionally, researchers are concerned about the misconduct inside the Chinese scientific community, such as fabrication, falsification and plagiarism, etc (Li, 2004; Wang, 2004).

We also find that China's manufacturing export competitiveness, particularly of high-tech products, is not established on the firms' dedication to R&D investment. This not only makes the explosive growth of China's high-tech product less respectable, but also casts doubt on Chinese industry's potential of moving up the ladder in global value chain. If Chinese firms are continuously obsessed in the trivial profit generated by processing trade, without endeavoring to develop own technological advantage, their current international competitiveness would not be guaranteed. In addition, our study shows that manufacturing activities of Hong Kong firms have not contributed to productivity gains in Guangdong's domestic manufacturing firms. In fact, productivity gains in Guangdong domestic firms result largely from their own commitment to R&D investment and efforts in innovation. All of these results invariantly reveal that establishing indigenous innovation capability is vital for a developing country such as China in terms of boosting productivity growth and enhancing industrial competitiveness. The challenges for the policy makers in China and other developing countries are how to take the effective policy actions to facilitate domestic firms to absorb the state-of-art technology and management knowledge to build up their own technological competitiveness.[41]

An additional finding of this study is that rigorous domestic competition contributes to the export success of China's manufacturing firms in labor-intensive and high-tech sectors. This evidence justifies a past policy, implemented in these sectors, which aimed to deregulate industry, encourage competition, and break up monopolies. The gradual divesture of government capital from the sectors in the past two decades has triggered the entry of private and foreign firms, bringing in keen competition that significantly enhances competitiveness among domestic firms in the global arena. The best examples of competitive domestic firms are the sub-sectors of consumer electronics, personal computers, and cell phones. When state-owned enterprises exited from these sectors, foreign investors grabbed a significant market share with their superior technological and management capability and forced domestic firms to restructure their backward production, management, and sales systems. Thanks to spillover and learning capability,

[41] In this regard, China's central government made an ambitious move in March 2006 through announcing its "home-grown" innovation strategy for the period of 2006-2020. The central object of this strategy is to foster the indigenous R&D and innovation activity in Chinese industry and reduce the dependence on foreign technology.

domestic firms benefited from “cut-throat” competition and gained on foreign rivals in terms of market share several years after the deregulation of the sector. The more successful domestic firms attained dominant market positions and began to expand globally. Thus, to reproduce the success of these sectors in other industries, Chinese policymakers should encourage competition, attract more foreign investors, foster technological learning and catching-up in domestic firms.

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